BBC

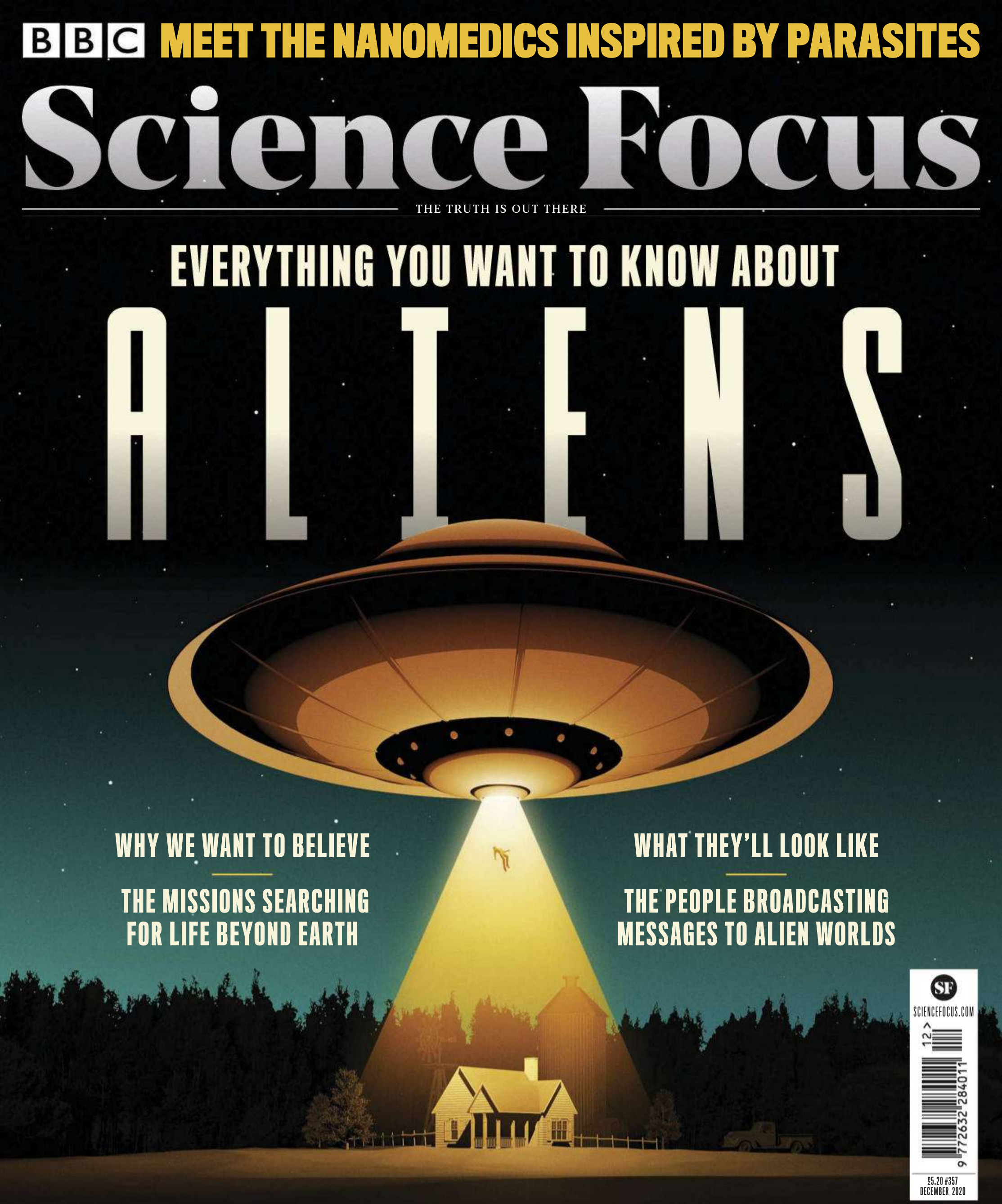
MEET THE NANOMEDICS INSPIRED BY PARASITES

Science Focus

THE TRUTH IS OUT THERE

EVERYTHING YOU WANT TO KNOW ABOUT

ALIENS



WHY WE WANT TO BELIEVE

THE MISSIONS SEARCHING FOR LIFE BEYOND EARTH

WHAT THEY'LL LOOK LIKE

THE PEOPLE BROADCASTING MESSAGES TO ALIEN WORLDS

SF
SCIENCEFOCUS.COM
12>
9 772632 284011
£5.20 #357
DECEMBER 2020

IN THIS ISSUE

COVID-19
Forget R, here's the number we should all understand

Nature
How you can help hedgehogs this winter

Tech
Inside the biggest camera on Earth

Change gear.

Trustpilot

Make. Good. Use.

Make good use of your used gear. Clear out your kitbag and cabinets, and sell what you're not using to free up funds or trade in towards your next kit purchase.

With 250,000 customers and five stars on Trustpilot, you can trust us and sleep easy. Free up funds without leaving the house. Safe, convenient, fully-insured. And completely free of charge.

mpb.com/info/make-good-use

FROM THE EDITOR

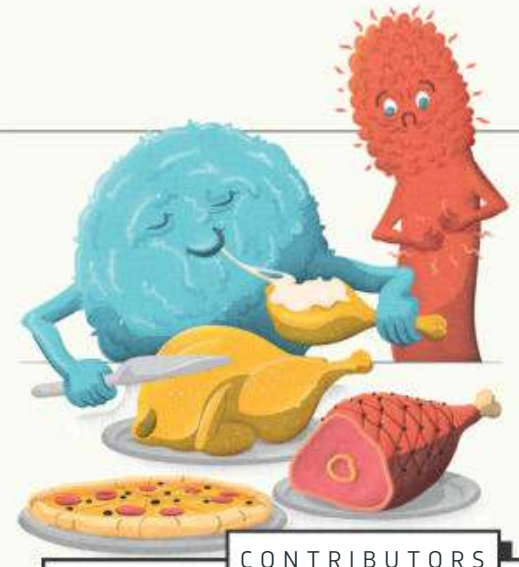
It turns out our Solar System is a pretty hospitable place. That's been one of the major narratives of the last decade as probes and rovers have stretched out across space and got to know the planets and moons that surround us. Clearly Earth is something special, but it seems that between the Martian rivers, the lakes on Europa and the seas of Enceladus there are plenty of niches in our cosmic neighbourhood where life could take a foothold. Despite this, it came as a huge shock when, in September, scientists announced that they had found the signature of a chemical, usually produced by living things, floating in the clouds of Venus. Indeed, it was such a surprise, that a paper was put out almost immediately disputing the data. Either way, aside from you-know-what, it was one of the biggest stories of the year, so it seemed a good moment to focus in on search for alien life and look at why we were so keen to find life out in the cosmos.

If you enjoy the issue, and want to know even more about alien lif, and the search for it, subscribe to our podcast. There you'll find the full half-hour interview with Dr Douglas Vokach, the president of METI (Messaging Extra-Terrestrial Intelligence) and more interviews with leading scientists looking for ET.

Enjoy the issue!

Daniel Bennett, Editor

WANT MORE? FOLLOW **SCIENCEFOCUS** ON FACEBOOK TWITTER PINTEREST INSTAGRAM



Why do we have favourite colours?
→ p79

CONTRIBUTORS

DR DOUGLAS VOKOCH

We're listening for aliens, but what if aliens are listening for us? Douglas, the President of METI wants us to start a conversation with ET. He tells us what he plans to say on

SUE NELSON

Aliens have never been far from the public consciousness. Science journalist and former BBC presenter Sue digs into why they have such a hold on our

PROF LEWIS DARNELL

It turns out we might not have to visit a Galaxy far, far away to discover alien life. It could be right on our cosmic doorstep. Astrobiologist Lewis gives us the run down

PROF DAVID GARCIA

As anyone on regular medication knows, keeping up with your treatment plan can sometimes be an issue. We speak to David about his high tech, parasite-inspired

CONTACT US

Advertising
sam.jones@immediate.co.uk
0117 300 8145
Letters for publication
reply@sciencefocus.com
Editorial enquiries
editorialenquiries@sciencefocus.com
0117 300 8755
Subscriptions
buysubscriptions.com/contactus
03330 162 113*
Other contacts
sciencefocus.com/contact

ON THE BBC THIS MONTH...

Nature Table Christmas Special
Sue Perkins is joined by comedians and wildlife lovers for this special episode of the BBC Radio 4 programme celebrating the natural world and its weird and wonderful flora and fauna.
Friday 25 December, 17:00-18:00

The 2020 RI Christmas Lectures
This year, three experts – geologist Chris Jackson, physicist and oceanographer Helen Czerski, and environmental scientist Tara Shine – present their take on a 'user's guide to life on Earth'.
BBC Four, check Radio Times for info

Brian Cox at the Barbican
What does it mean to live in a small, finite life in a possibly infinite, eternal universe? Brian Cox and the BBC Symphony Orchestra bring music and science together to try to find the answer.
BBC Radio 3, check Radio Times for info

COVER: MAGIC TORCH THIS PAGE: BBC, GETTY IMAGES X2, JANICE AITKEN, DANIEL BRIGHT

*Calls from landlines will cost up to 9p per minute. Calls from mobile phones will cost between 3p and 55p per minute but are included in free call packages. Lines are open 8am-5pm weekdays. If calling from overseas, please call +44 1604 973 721.

BBC Science Focus (ISSN 0966-4270) (USPS 015-160) is published 14 times a year (monthly with a Summer issue in July and a New Year issue in December) by Immediate Media Company, Bristol, Eagle House, Colston Avenue, Bristol, BS1 4ST. Distributed in the US by Circulation Specialists, LLC, 2 Corporate Drive, Suite 945, Shelton, CT 06484-6238. Periodicals postage paid at Shelton, CT and additional mailing offices. POSTMASTER: Send address changes to *BBC Science Focus*, PO Box 37495, Boone, IA 50037-0495.

CONTENTS

REGULARS

06 EYE OPENER
Incredible images from around the world.

10 CONVERSATION
What's been in our inbox this month.

13 DISCOVERIES
The month's biggest science news. Water on the Moon; ancient marine reptile could float underwater; early Andean hunters were women; secrets of the unsquashable beetle revealed.

28 REALITY CHECK
The science behind the headlines. This month: Are hedgehogs going extinct in the UK? Forget about the R value, the K number is the one that can help us understand the coronavirus. How do we count the number of COVID-19 deaths?

63 ALEKS KROTOSKI
The 24-hour world of the internet has banished the night. Only by going offline can we seek some stillness and hush the din.

64 MICHAEL MOSLEY
Walking in the outdoors is a great form of exercise, but you could reap more benefits – and even smile more broadly – if you truly appreciate your surroundings.

77 Q&A
Our experts answer your questions. This month: Should I really starve a fever and feed a cold? Why do I always cry when I watch films on a plane? What is a white hole? How does bubble wrap become bubbly? Why does running water make me need the toilet?

89 CROSSWORD
Get your grey matter churning with our tricky cryptic crossword.

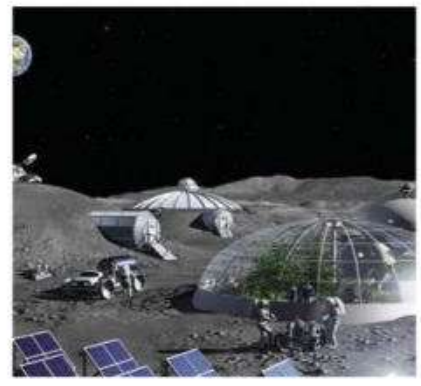
89 NEXT MONTH
Take a look at what's in store in next month's *BBC Science Focus*.

90 A SCIENTIST'S GUIDE TO LIFE
Dreading a visit from the in-laws from hell this Christmas? Don't worry, psychologist Linda Blair is here to help you have a stress-free festive period.

60 SUBSCRIBE TODAY!

Save 52% when you subscribe to *BBC Science Focus* today!

13 DISCOVERIES



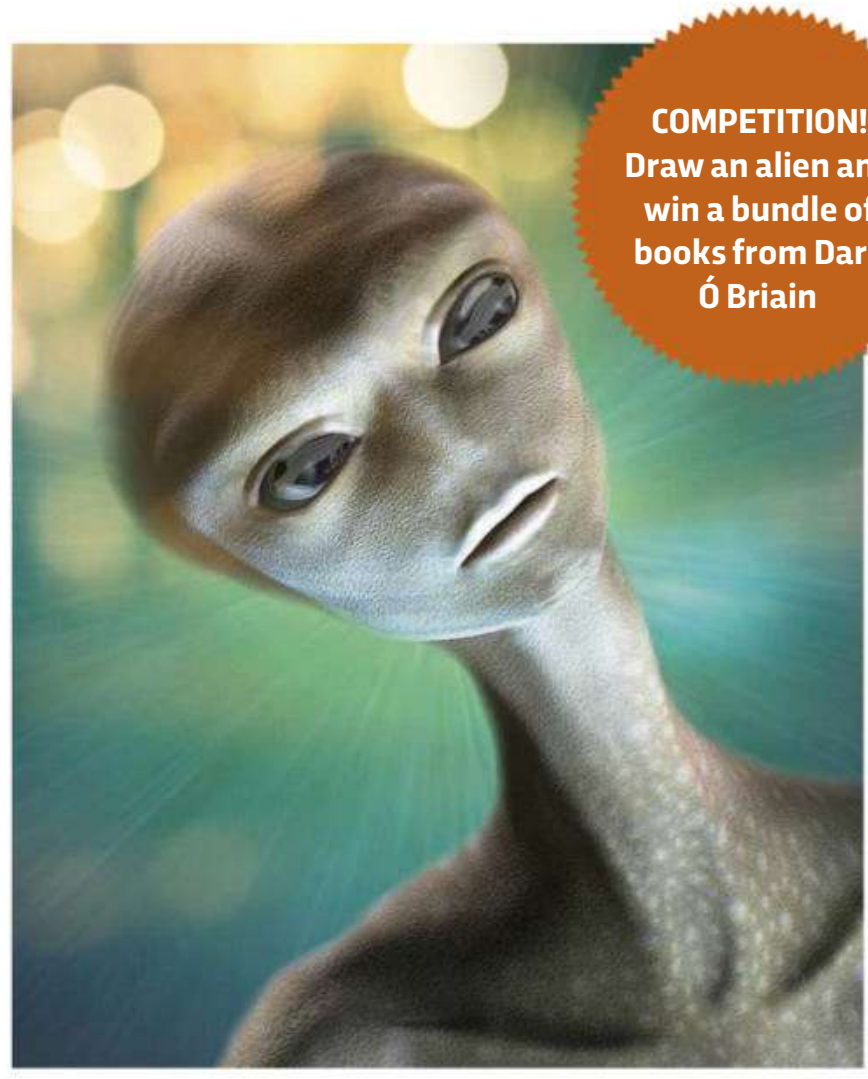
Water pockets found on the Moon could quench the thirst of future astronauts.

28 REALITY CHECK

Could everyone's favourite British mammal, the hedgehog, go extinct in the UK?

86 WHAT DO ALIENS LOOK LIKE?

Get the lowdown on what aliens could look like from zoologist and astrobiologist Dr Arik Kershenbaum, then draw your own. Dara Ó Briain will pick his favourite, and the winner will receive a bundle of his books.



COMPETITION! Draw an alien and win a bundle of books from Dara Ó Briain

FEATURES

34 CHRISTMAS GIFT GUIDE
Gadgets and goodies galore.

44 UNIVERSE, SAY CHEESE!
The camera that could change our view of the cosmos.

52 WHERE ARE THE ALIENS IN OUR SOLAR SYSTEM?
The best candidates for alien life in our neighbourhood.

66 SHOULD WE BE SIGNALLING OUR EXISTENCE TO ALIEN LIFE?
We talk to METI president Dr Douglas Vakoch.

70 WHY WE WANT TO BELIEVE
Why do aliens have such a hold on our collective psyche?

52
WHERE ARE THE ALIENS IN OUR SOLAR SYSTEM?

34
CHRISTMAS GIFT GUIDE

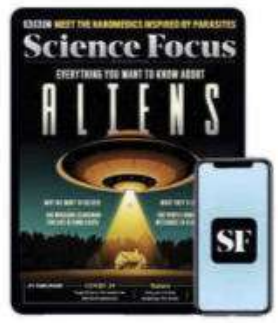
Dear Santa, we've been very good this year.

66
DR DOUGLAS VAKOCH

"THE PURPOSE OF METI IS TO REACH OUT TO ANOTHER CIVILISATION AND SAY NOT ONLY ARE WE HERE, BUT WE WANT TO MAKE CONTACT"

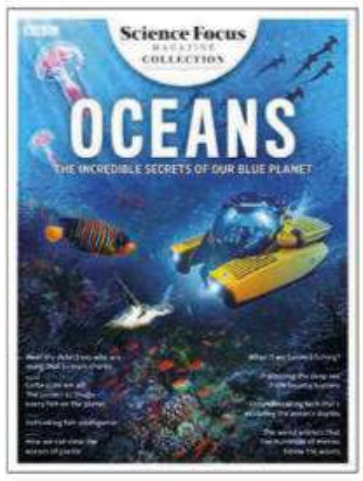
WANT MORE?

Don't forget that *BBC Science Focus* is also available on all major digital platforms. We have versions for Android, Kindle Fire and Kindle e-reader, as well as an iOS app for the iPad and iPhone.



Can't wait until next month to get your fix of science and tech? Our website is packed with news, articles and Q&As to keep your brain satisfied.
sciencefocus.com

SPECIAL ISSUE



OCEANS: THE INCREDIBLE SECRETS OF OUR BLUE PLANET
In this special edition, the experts from *BBC Science Focus* don their diving kit and take the plunge into the depths of the oceans, to reveal more about the incredible world beneath the waves.
buysubscriptions.com/focuscollection

EYE OPENER

Happy hour

NORTH AMERICA

At just 8cm long, the lesser long-nosed bat (*Leptonycteris yerbabuenae*) has a tongue almost as long as its body, allowing it to reach nectar from night-blooming agave plants. It's one of only three nectar-feeding bat species in the US. When it feeds, the bat gets covered in pollen, which it carries to another plant, cross-fertilising it in the process. This mutual relationship between the bats and the agave has evolved over time.

The juices of agave plants are distilled to make tequila. So great was the demand for the beverage, that workers began cloning the plant, instead of allowing natural bat pollination, and harvesting the agave before it flowered. Bat numbers declined, and the cloned plants were more vulnerable to disease.

Conservationists have been working to restore numbers by establishing a 'bat-friendly' tequila. And in 2015, the bats were removed from the endangered species act.

We'll drink to that.

TOM VEZO/MINDEN PICTURES/FLPA

VISIT US FOR MORE AMAZING IMAGES:

SCIENCEFOCUS

BBCSCIENCEFOCUS

EYE OPENER

Antibody ready

VISP, SWITZERLAND

Producing enough of the COVID-19 vaccine requires hygienic and sterile manufacturing facilities, and Swiss biotechnology company, Lonza, is determined to be ready by the end of the year.

Currently in trials, the Moderna vaccine (mRNA-1273), is being partly manufactured at Lonza. One of the global frontrunners, Moderna's vaccine uses mRNA technology. It works by taking the genetic information for a spike protein located on the surface of the coronavirus. The genetic instructions for making this protein are then encoded into an mRNA molecule, which is given as a vaccine. The immune system can then learn and recognise the spike protein, and develop ways to defeat it if the coronavirus ever enters the body. RNA vaccines can be produced quickly in a lab, so for facilities like this one in Switzerland, the race is on to ensure they are able to begin production as soon as a vaccine is approved.

SHUTTERSTOCK

VISIT US FOR MORE AMAZING IMAGES:

SCIENCEFOCUS

BBCSCIENCEFOCUS

CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND *BBC SCIENCE FOCUS*

reply@sciencefocus.com
BBC Science Focus, Eagle House, Colston Avenue, Bristol, BS1 4ST
@sciencefocus
www.facebook.com/sciencefocus
@bbcsciencefocus

LETTER OF THE MONTH

Itching to know

I have enjoyed the scientific education that *BBC Science Focus* has brought my family and I ever since the first issue. However, occasionally I have to raise an eyebrow at some of the subject matter. In 'Don't scratch that itch' (October, p16), experiments were conducted on mice to discover whether it is better to scratch or rub an itch. In a time when our relationship with the natural world is rightly under immense scrutiny, surely we should question the use of animals for such research? What's more, I've known the answer to this for many years – if in any doubt, the researchers could have just asked a few humans.

Eugene Day

WORTH £76.94

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins a **bundle of shortlisted books from the Royal Society Science Book Prize**. These six game-changing reads come from authors Bill Bryson, Jim Al-Khalili, Gaia Vince, Camilla Pang, Susannah Cahalan and Linda Scott, and have been praised for combining rigorous science with engaging storytelling. **royalsociety.org**

Veganism: milking it?

I felt your article 'Going vegan could help to fight climate change' (October, p15) gave too simplistic a view. Most non-dairy 'milks' can hardly be called eco-friendly; soya has to be shipped over thousands of kilometres and much is grown in destroyed Amazon rainforest, while almonds are mainly grown in California using large amounts of underground water (which is not being replaced). There are a number of eco and other objections to veganism. So, the case for going vegan is neither complete, nor simple, and I feel deserves better discussion.

Dr Peter Stokes, Beckenham

On my mind

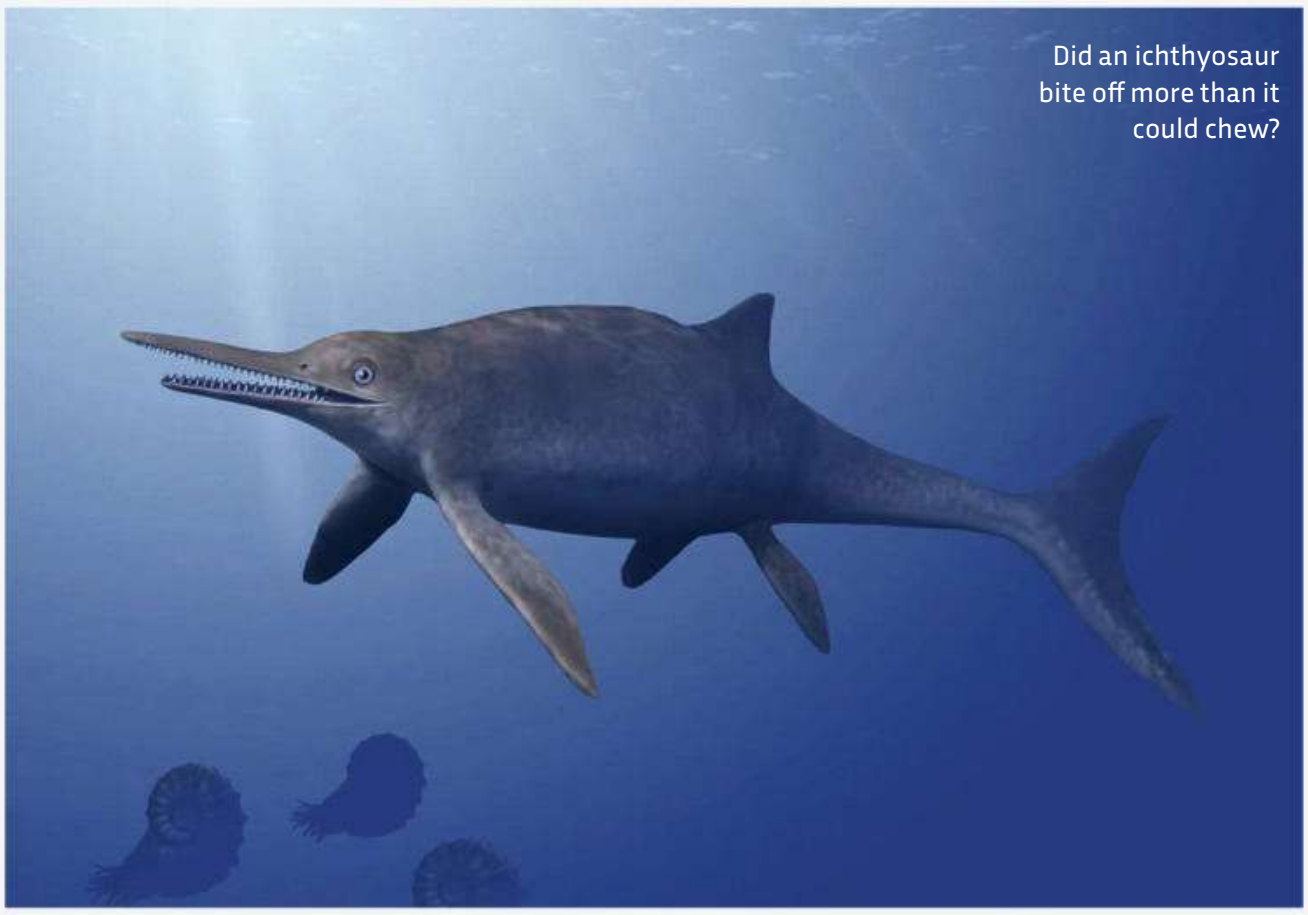
At 80, (and having spent 27 years on antidepressants until 10 months ago), the present world holds no fears or anxieties for me. You might call it resilience (October, p70), I call it peace of mind. To me, a thought is neither negative, nor positive. They are adjectives imposed by an external source.

Philip Noble, St Ives

Soya for plant-based milks is grown in destroyed rainforest, says Peter Stokes

"WHAT WE'RE TRYING TO DO WITH METI, IS TO REACH OUT TO ANOTHER CIVILISATION AND SAY NOT ONLY ARE WE HERE, WHICH YOU ALREADY KNOW, BUT WE WANT TO MAKE CONTACT"

DR DOUGLAS VAKOCH, P66



Did an ichthyosaur bite off more than it could chew?

A late lunch

I have just read your article about the ichthyosaur that consumed an animal nearly as large as itself (October, p17) taken as proof of megapredation. But, as the animal died shortly after swallowing the thalattosaur, could it be a case of biting off more than you can chew? It might've been swallowing the animal that killed the ichthyosaur, and not megapredation.

Michael Stockford, Northampton

Trust Silicon Valley?

In the explainer on artificial intelligence (September, p86) you asked whether AI can be trusted. Despite pointing out that trusting AI too much can get us into trouble, you end by saying AI is not to be feared. But a machine that uses AI and machine learning is unable to explain its decisions and actions to human users. This form of AI is therefore unsuited to applications where there is a need to understand relationships or causality; instead, they mostly perform well in applications where one only needs predictions.

Unfortunately, their use won't be limited – tech giants seem to be applying machine learning to all their operations.

Steve Jones, Bedford

Driverless cars still need a driver behind the wheel

GETTY IMAGES X2, ALAMY X2

THE TEAM

EDITORIAL
Editor Daniel Bennett
Managing editor Alice Lipscombe-Southwell
Commissioning editor Jason Goodyer
Editorial assistant Amy Barrett
Online assistant Sara Rigby

ART
Art editor Joe Eden
Picture editor James Cutmore

CONTRIBUTORS
Scott Balmer, Rob Banino, Noah Bavonese, Juanita Bawagan, Abigail Beall, Peter Bentley, Dan Bright, Steve Brusatte, Marcus Chown, Stuart Clark, Lewis Dartnell, Emma Davies, Cathal Duane, Alexandra Franklin-Cheung, Alice Gregory, Alastair Gunn, Brenna Hassett, Ben Hoare, Ben Holder, Adam Hylands, Christian Jarrett, Arik Kershenbaum, Aleks Krotoski, Magic Torch, Nish Manek, Robert Matthews, Michael Mosley, Sue Nelson, Stephanie Organ, Helen Pilcher, Jason Raish, Jeremy Rossman, Helen Scales, Holly Spanner, Luis Villazon.

ADVERTISING & MARKETING
Group advertising manager Tom Drew
Advertisement manager Sam Jones 0117 300 8145
sam.jones@immediate.co.uk
Business development manager Dan Long
daniel.long@immediate.co.uk
Newstrade manager Helen Seymour
Subscriptions director Jacky Perales-Morris
Direct marketing manager Kellie Lane

MOBILE
Head of apps and digital edition marketing
Mark Summerton

INSERTS
Laurence Robertson 00353 876 902208

LICENSING & SYNDICATION
Director of licensing and syndication Tim Hudson
International partners manager Anna Brown

PRODUCTION
Production director Sarah Powell
Production coordinator Georgia Tolley
Ad services manager Paul Thornton
Ad coordinator Florence Lott
Ad designer Julia Young

PUBLISHING
Commercial director Jemima Dixon
Content director Dave Musgrove
Group managing director Andy Marshall
CEO Tom Bureau

BBC STUDIOS, UK PUBLISHING
Chair, editorial review boards Nicholas Brett
Managing director, consumer products and licensing
Stephen Davies
Head of publishing Mandy Thwaites
Compliance manager Cameron McEwan
UK publishing coordinator Eva Abramik
Contact UK.Publishing@bbc.com
www.bbcstudios.com

EDITORIAL COMPLAINTS
editorialcomplaints@immediate.co.uk

ANNUAL SUBSCRIPTION RATES (INC P&P):
UK/BFPO £72.80; Europe & Eire £77.80; Rest of World £82.80.

Audit Bureau of Circulations
44,687 (combined, Jan-Dec 2019)

IMMEDIATE MEDIA Co

ipso Regulated

BBC Science Focus Magazine is published by Immediate Media Company London Limited under licence from BBC Studios who help fund new BBC programmes.

© Immediate Media Co Bristol Ltd 2020. All rights reserved. Printed by William Gibbons Ltd.

Immediate Media Co Bristol Ltd accepts no responsibility in respect of products or services obtained through advertisements carried in this magazine.

recycle

Thank you, Sylvia

Sylvia left a gift in her Will to help conquer Stroke

The first we knew of Sylvia was when we received notification of the gift she'd left us in her Will. Shortly after, a beautiful story of a much-loved woman began to unfurl.

Friends remembered Sylvia's kind-heart and her wish to help others. She spent part of her adult-life caring for her mother, and developed a passion for medicine. Becoming a medical secretary was her next step and, in the course of her career, she discovered the devastating impact a stroke could have on people and their families. She saw that research and treatment were vastly under-funded, and she decided to remember the Stroke Association in her Will.

Sylvia's gift has helped fund our work to conquer stroke. She's supported research to prevent and treat stroke, and she's helped care for survivors. And that's something you can do too – in the same way.

If you would like to learn more about remembering the Stroke Association in your Will, please get in touch.

Call 020 75661505 email legacy@stroke.org.uk or visit stroke.org.uk/legacy

Stroke association

Registered office: Stroke Association House, 240 City Road, London EC1V 2PR. Registered as a Charity In England and Wales (No 211015) and In Scotland (SC037789). Also registered in Northern Ireland (XT33805), Isle of Man (No 945) and Jersey (NPO 369). Stroke Association Is a Company Limited by Guarantee In England and Wales (No 61274)

WINGING IT
Aircraft engineers take inspiration from owls **p17**

BADASS BEETLE
Secrets of unsquashable beetle revealed **p18**

WOMAN THE HUNTER
Game hunter from ancient Americas was female **p19**

HIGH FLIERS
Aerospace start-up reveals supersonic jet **p20**

DISCOVERIES

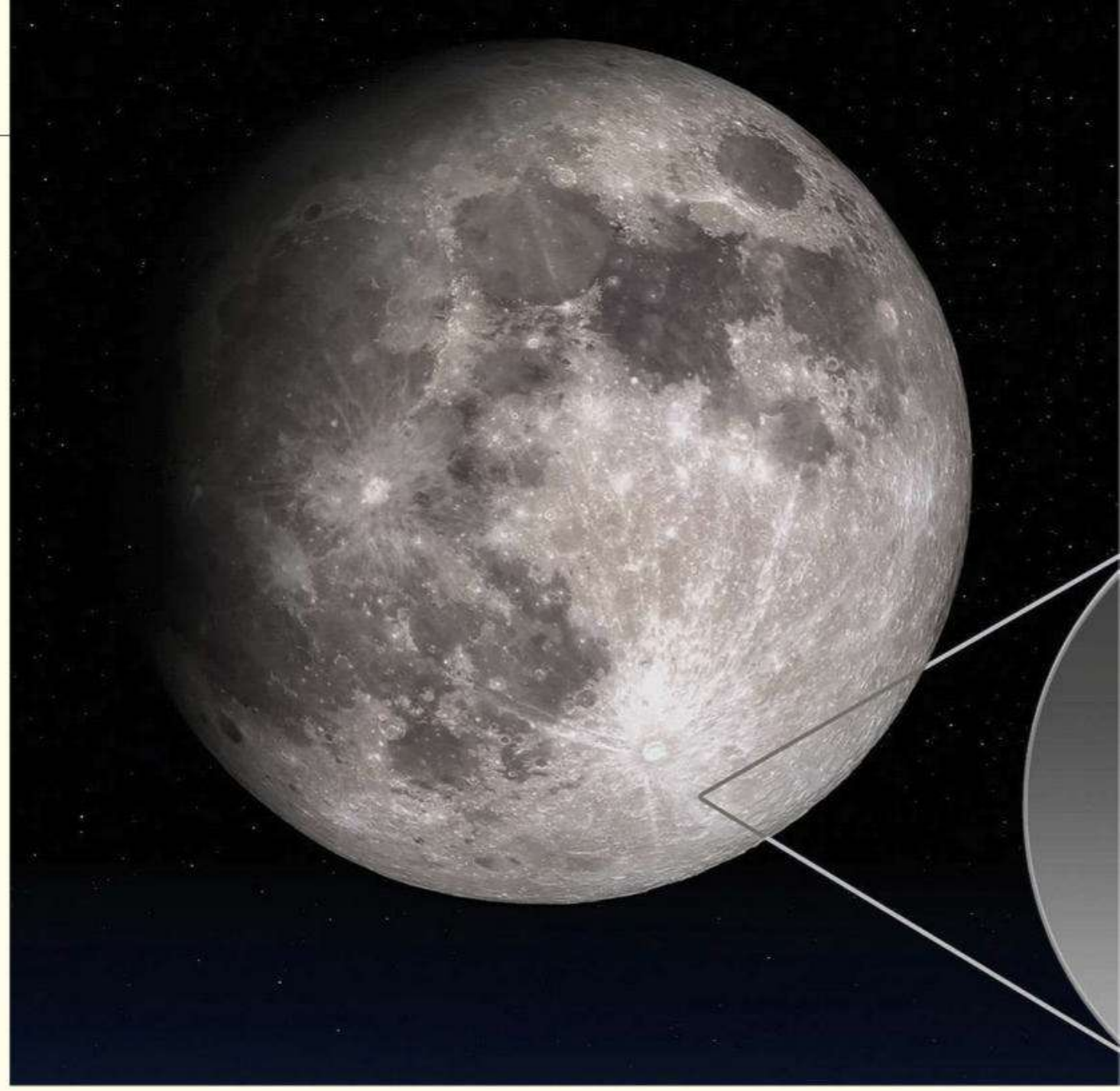
WATER FOUND ON THE MOON COULD QUENCH FUTURE ASTRONAUTS' THIRST

Water could be more widespread on the Moon than previously thought. New readings from NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) indicate that molecular water (H_2O) is present in the Clavius crater, one of the largest craters on the Moon. This discovery is important because water was thought to be present on the Moon only in the permanently shadowed regions near the lunar poles. Although Clavius is in the southern hemisphere at a relatively high latitude, its interior is exposed to sunlight. Since it seems that water can survive at or near the lunar surface here, it implies that water may be much more widely distributed across the lunar surface than previously recognised.

"Without a thick atmosphere, water on the sunlit lunar surface should just be lost to space," said Dr Casey Honniball of NASA's Goddard Space Flight Center in

SCIENCE PHOTO LIBRARY

Fearsome floater Newly discovered ancient marine reptile could float underwater p22 **Micro machines** Tiny, parasite-inspired robots deliver medicine via the intestines p24



Greenbelt, Maryland, and the lead author of the new work. "Yet somehow we're seeing it. Something is generating the water, and something must be trapping it there."

But if it's such a mystery how the water got there, could it mean the NASA researchers have made a mistake in their identification of the molecule? Prof Mahesh Anand, a planetary scientist from The Open University, UK, has studied the discovery and thinks the work is sound. "I think that the researchers have done a very good job in confirming that the spectral signature they are looking at can only be provided by molecular water," he said.

Even so, the abundance of the water is not high. For comparison, the Sahara Desert possesses 100 times more water than was found in the lunar surface material by SOFIA.

Nevertheless, it is a potentially important discovery because the more water there is on the Moon, the easier it will be to set up a lunar base. The water could be extracted to drink, to make oxygen, and also to make rocket fuel.

Q&A WITH PROF MAHESH ANAND

HOW SIGNIFICANT IS THIS FINDING?

Finding the signature for the presence of molecular water in the sunlit portion of the Moon is what makes this more significant than perhaps it would have been, because water has been detected previously on the surface of the Moon.

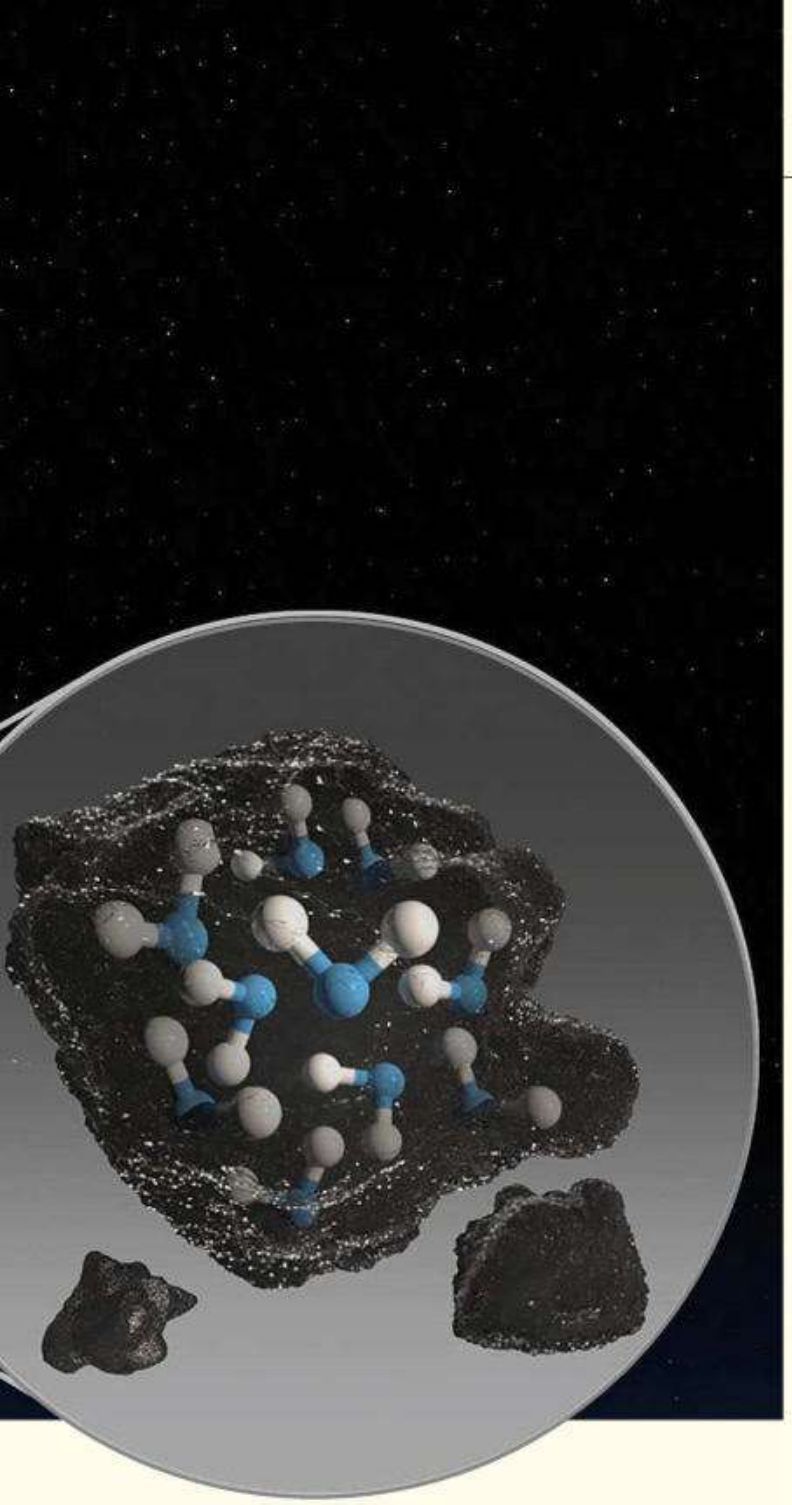
Finding water on the Moon is not totally unexpected, but what was not known before was whether this water was present as hydroxyl, which is one atom of oxygen attached to an atom of hydrogen, or H_2O, which is two hydrogen atoms attached to one oxygen. The latter is molecular water and is what a layperson would understand as water. Molecular water, arguably, has only been detected once before on the Moon, when the LCROSS [Lunar Crater Observation and Sensing Satellite] impactor hit a permanently shaded crater in the southern polar region. So, whatever was there was lifted up in the ejecta plume in which some water ice was detected. But molecular water as such had not been confirmed in the sunlit areas of the Moon, which I think is why this discovery is very exciting.

Scientifically, water or hydroxyl on the Moon could have different origins, which could have quite a different meaning and significance in terms of what its physical status might be, how much is present, and how amenable it might become to future explorers for using it as a resource.

WHY HAS IT TAKEN SO LONG TO FIND WATER?

I think we have to put ourselves back in the early 1970s [the Apollo missions], when humans first visited the Moon and returned to Earth with some lunar samples. Once the Moon's dust or rock samples were back on Earth, there was a lot of work done to ascertain whether there was any hint of water. There was none, but that was with the technology that was available at that time. We must remember that the Apollo missions did not go in search of water. So in some ways, the right questions weren't posed at the time. Instead, the question posed was, can humans actually safely land on the Moon and then return to Earth?

There was speculation, even before the Apollo era, that there could be water in the permanently shadowed regions of the Moon. The problem was that none of the Apollo missions, or any subsequent missions until



ABOVE Visualisation of water molecules in the Moon's Clavius crater

LEFT SOFIA is a modified Boeing 747SP jetliner with a telescope onboard. Flying at high altitudes, it can see the signature of celestial water without interference from Earth's water vapour

NASA/JPL

the 1990s, were equipped with an instrument that could detect anything inside these cold, dark craters. That didn't happen until the 1990s when two missions, Clementine and Lunar Prospector, were sent to the Moon.

WHERE DID THE LUNAR WATER COME FROM?

Right! Finding water is one thing but the next question is, where did that water come from? Hydrogen occurs in two forms [isotopes]. One is hydrogen as we know it, which has one proton in its nucleus. The other is called deuterium, which contains a proton and a neutron. The Sun gives out almost pure hydrogen in the solar wind, but deuterium-enriched materials exist in the outer Solar System, meaning it could have come from much further out in the Solar System or even beyond.

So imagine a scenario where a comet from far away has collided with the Moon and delivered a lot of water-rich material to the lunar poles. The water from the comet will have a unique hydrogen isotope composition compared to water built from hydrogen from the solar wind or through volcanic eruptions on the Moon itself. It's like the comet's own DNA for water. If I were to then go and collect the lunar dust from this polar region, where the comet has contributed some water, and I brought it back into the lab, I could measure the isotopic composition of the water, alongside how much water is present. I will be able to say X per cent of this water is of cometary origin. So, the combination of measuring the amount of water and the isotopic composition will tell us a great deal about where that hydrogen, and so the water, might have come from.

DOES THIS MAKE THE PROSPECT OF HUMAN EXPLORATION OF THE MOON EASIER?

The south polar region is popular right now as a destination because that's where multiple missions have already indicated the possible presence of water in the permanently shaded craters. But now, if we are also seeing the possibility of some form of water in non-shaded regions, then that means that you improve your chances of actually finding water without risking your life or instruments going down into a hole, which may be less than -200°C. And this is not just about taking someone to the Moon. If you think about it, the inspirational value this has for the next generation of scientists and engineers is tremendous. What it shows is that when you actually look deep enough, and have a curious mind, you make these discoveries that nobody had thought possible.

by **DR STUART CLARK**

Stuart is an astronomy writer. His latest book is Beneath The Night *(£14.99, Guardian Faber).*

In numbers

£24.7 million

The price of an adult male *T. rex* skeleton recently sold at Christie's Auction House to an anonymous telephone bidder – the most expensive dinosaur remains ever. It was discovered by an amateur palaeontologist in South Dakota in 1987.

12,070 km

The distance flown by a bar-tailed godwit, a new record for non-stop bird migration. The bird was tracked by a team from the University of Groningen, the Netherlands, as it made its epic journey from Alaska to New Zealand in just 11 days.

90 per cent

The proportion of all life on Earth wiped out following a volcanic eruption in Siberia that occurred 252 million years ago, a study at the University of St Andrews has found. Known as the 'Great Dying', the eruption spewed tonnes of carbon dioxide into the atmosphere and oceans.

PALAEONTOLOGY

First sabre-toothed cat genome reveals a lethal long-distance hunter

Mo Farah's got nothing on this long-distance runner. The first sabre-toothed cat genome has revealed that the animal was a specialist at hunting prey over long distances. The cat's DNA was extracted from the fossil of a particular species of sabre-toothed cat known as the scimitar-toothed cat (*Homotherium latidens*). Like other sabre-toothed cats, it went extinct towards the end of the Pleistocene, around 10,000 to 30,000 years ago. This particular specimen, found in permafrost sediments near Dawson City, Yukon Territory, Canada, was at least 47,000 years old.

A team at the University of Copenhagen used genome-sequencing techniques to read the entire genetic code that would've been packed into each of the animal's cell nuclei (its 'nuclear genome'). The cat's genetic makeup hints that it was a highly skilled long-distance hunter.

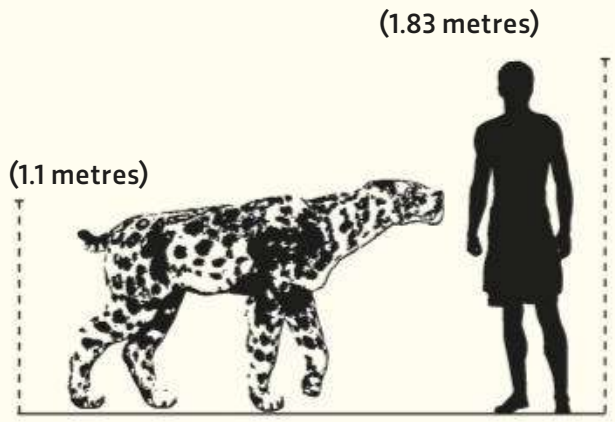
"They likely had very good daytime vision and displayed complex social behaviours," said co-first author Dr Michael Westbury. "They had genetic adaptations for strong bones and cardiovascular and respiratory systems, meaning they were well suited for endurance running. Based on this, we think they hunted in a pack until their prey reached exhaustion."

Animals are known to use this hunting technique, called endurance hunting, when they're slower than their prey over short distances, but have the stamina to win out over the longer chases.

The genetic analysis also showed that all modern cats are very distantly related to sabre-toothed cats, branching off from them on the evolutionary tree at least 22.5 million years ago. By comparison, humans and gibbons split between 15 and 20 million years ago.

Sabre-toothed cats were more genetically diverse than modern cats, which means that there were likely a lot of them around – indeed, their fossils have been found worldwide.

"This was an extremely successful family of cats," said co-first author Dr Ross Barnett. "They were present on five continents and roamed the Earth for millions of years before going extinct. The current geological period is the first time in 40 million years that Earth has lacked sabre-tooth predators. We just missed them."



ABOVE RIGHT Size comparison of a scimitar-toothed cat and a human

BELOW Evidence suggests that scimitar-toothed cats were endurance hunters, chasing their prey down over long distances

ENGINEERING

Owl's flight through gusty winds could inspire new aircraft designs

A new understanding of how birds' wings change in turbulent flying conditions has implications for the future of aircraft

Birds have been a huge inspiration for many technologies in the aviation industry, but human aircraft cannot yet match their ability to fly straight and steady through storms. However, a team of scientists from the University of Bristol and the Royal Veterinary College have uncovered birds' secret to combatting wind speeds as fast as their own flight.

"We've been flying for over 100 years, ever since the Wright brothers [who built and flew the first powered plane]. They knew that getting enough lift to fly was a challenge, but that was easier when compared with stabilising and controlling the flight," said Prof Richard Bomphrey, one of the study's authors from the Royal Veterinary College.

"They had a method for controlling the Wright Flyer that worked reasonably well – a series of cables which twisted the wing. But ever since then, we've built a rigid winged aircraft, mainly because the maths is a bit easier. It's easier to create wings which are stiff, and then they behave in a more predictable manner."

This works for certain flying conditions, where a rigid wing shape is optimal. But to improve flight performance in strong winds, a different, bio-inspired design for the wings of an aircraft would be better, said Bomphrey.

To find out how birds cope with wind, the team observed the flight of a goshawk, a tawny eagle, a tawny owl and a barn owl. The latter, who was named Lily, is the star of the team's publication in *Proceedings Of The Royal Society B*.

"We built a gust generator so we could set the speed and direction of the wind, and then encouraged Lily to glide just where we wanted her to go," said Bomphrey. "We had high-speed cameras and some motion capture cameras set on her, with which we could do a process called stereophotogrammetry – a way of getting three-dimensional shapes from a pair of cameras."

Watching Lily through these cameras, the team discovered that during flight her wings acted as a suspension system, stabilising the trajectory of the head and the torso in strong winds.

"[The wing] does this in a rather elegant way, which should be quite familiar to people who play any bat-and-ball games or racquet sports. That's the concept of the sweet spot," said Bomphrey. "So if you are playing cricket and as the heavy ball comes down you hit it with the very end of the bat, the handle will jump out of your hands forward. Whereas if you hit the ball right up close to the handle, then the handle gets shoved backwards. That tells you that there's a point between those two areas where you might hit the ball and the handle doesn't get jarred forwards or backwards. If you're lucky enough to hit a ball as well as that, then it feels effortless."

Bomphrey says the bird's wing can be thought of as the bat, and the gust of wind as the ball. In changing weather conditions, the bird pivots her wings around the shoulder, so the gust hits in that sweet spot, all the forces and torques cancel at the hinge of the shoulder joint. The wing moves, but the body doesn't.

The team say this knowledge could inspire new designs for the aviation industry, initially starting with small scale and non-manned aircraft but eventually influencing passenger planes.

"[The technology] is totally ready to go, because it's a phenomenon that we've observed in birds. The key part is that you must have the hinge, and you must have the right alignment. That can be done just by moving where the [mass is]," said Bomphrey. "We've actually done a bit of prototyping ourselves already with some toy gliders, demonstrating the same principle that we've seen in birds, rejecting about 40 per cent of exactly the same gust, in the lab, with no onboard computer whatsoever."

UNIVERSITY OF COPENHAGEN, ALAMY

Source of near-indestructible beetle's toughness discovered

Found in the desert in the southwestern USA, the diabolical ironclad beetle has an exoskeleton so strong it can survive being run over. Materials scientists at the University of California, Irvine, have discovered what makes this tiny titan so tough, and they have made composite materials with the same characteristics.

"The ironclad is a terrestrial beetle, so it's not lightweight and fast, but built more like a little tank," said Dr David Kisailus, principal investigator on the study. "That's its adaptation: it can't fly away, so it just stays put and lets its specially designed armour take the abuse until the predator gives up."

The team studied the beetles with compression tests and found that they could withstand a force 39,000 times their own body weight. That's like a 60kg person surviving a 2,340-tonne weight.

The insect's remarkable strength lies in its elytra. In flying beetles, the elytra are hardened forewings that close over their hindwings – which do the flying – and protect them from bacteria and damage. In the diabolical ironclad beetle, the elytra have fused together, forming a tough shield.

The researchers studied the elytra using microscopy and spectroscopy. They found that they are made up of a protein matrix and layers of chitin, a fibrous material often found in insects' exoskeletons. Compared to a flying beetle, the ironclad's elytra had about 10 per cent more protein by weight.

They also looked at how the two halves of the elytra were attached – known as the medial suture. The join looks like interlocking jigsaw pieces, but they don't behave as you might expect.

"When you break a puzzle piece, you expect it to separate at the neck, the thinnest part," said Kisailus. "But we don't see that sort of catastrophic split with this species of beetle. Instead, it delaminates, providing for a more graceful failure of the structure." That is, the layered structure of the chitin saves the day: instead of suddenly breaking, the layers slowly fracture and come apart.

Kisailus and his team have taken inspiration from these remarkable beetles to design a material with the same interlocking pieces. When they joined the material to an aluminium coupling, they found it was much stronger and tougher than standard fasteners.

The researchers hope that this could be used in aircraft to join segments together without the weak points that traditional rivets and fasteners introduce.

The diabolical ironclad beetle has incredibly tough forewings that could inspire new materials

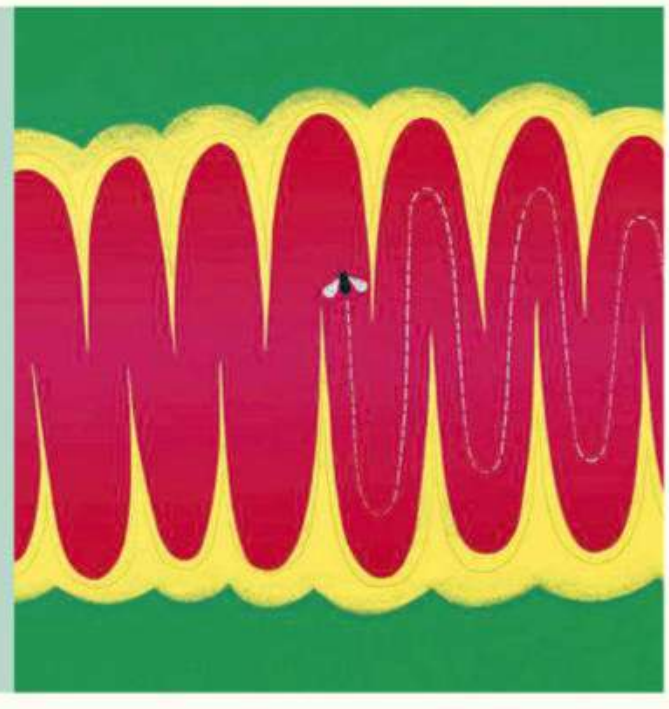
They did what?

Venus flytraps given memory tests

WHAT DID THEY DO?
Scientists at the National Institute for Basic Biology in Okazaki, Japan, tested the 'short-term memory' of Venus flytraps by adding genes to them that produce a protein that glows green when exposed to calcium – an element thought to be involved in the plants' memory mechanisms.

WHAT DID THEY FIND?
When the team tapped one of the plant's sensory hairs, a glow began at the base of the hair, before spreading through the leaf and eventually fading. When they touched the same hair a second time, or even a different hair on the leaf, within 30 seconds, the trap's leaves lit up even brighter than before, and its jaws quickly snapped shut.

WHAT DOES THAT MEAN?
The results show that the flytrap's 'short-term memory' is a waxing and waning of calcium within the leaves' cells, the researchers say. Each time a sensory hair is triggered, it signals the release of calcium. When the calcium concentration reaches a certain level, the trap closes.



GETTY IMAGES, MATTHEW VERDOLIVO/UC DAVIS IET ACADEMIC TECHNOLOGY SERVICES

HUMANS

Earliest big-game hunter ever found in the Americas was female

FINDING CHALLENGES LONG-HELD 'MAN-THE-HUNTER' HYPOTHESIS

For centuries, historians and scientists have agreed that when early human groups sought food, it was the job of men to hunt, and the job of women to gather. Now, the discovery of a 9,000-year-old body of female hunter buried in the Andean Mountains of South America has revealed a different picture, US researchers say.

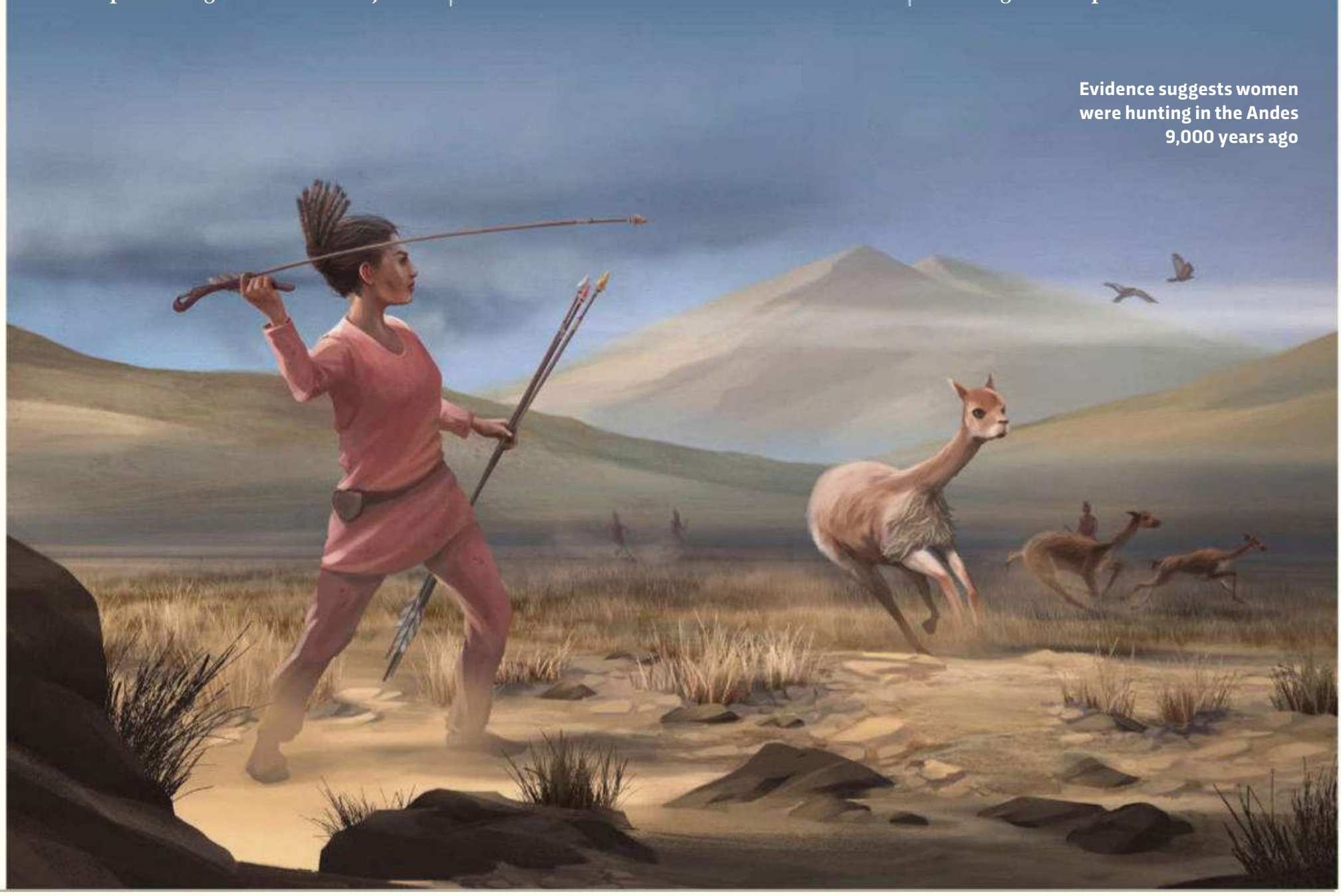
In 2018, archaeological excavations at Wilamaya Patjxa, in what is now Peru, uncovered an early burial site that contained a 'hunting toolkit' made up of various weaponry and animal-processing tools. As the objects accompanying people in death tend to be those that accompanied them in life, it can be assumed that the person buried here was a hunter, the researchers say.

Following a subsequent analysis of the bones, the team's osteologist James Watson of the University of Arizona determined that they belonged to a female. This was later confirmed by dental protein analysis carried out at the University of California, Davis.

The surprising discovery led the team to investigate other records of late Pleistocene and early Holocene burials unearthed across North and South America to determine whether the female hunter was part of a broader pattern.

Of the 429 burials they found, 27 individuals were linked to big-game hunting tools, with 15 of these being male and 11 female. Plus, the analysis identified the Wilamaya Patjxa female hunter as the earliest hunter burial ever found in the Americas.

"We believe that these findings are particularly timely in light of contemporary conversations surrounding gendered labour practices and inequality," said Dr Randy Haas, assistant professor of anthropology at UC Davis and the lead author of the study. "Labour practices among recent hunter-gatherer societies are highly gendered, which might lead some to believe that sexist inequalities in things like pay or rank are somehow 'natural'. But it's now clear that sexual division of labour was fundamentally different – likely more equitable – in our species' deep hunter-gatherer past."



Evidence suggests women were hunting in the Andes 9,000 years ago

1

ENGINEERING

Aerospace start-up unveils first-ever independently developed supersonic jet

Boom Supersonic recently unveiled the XB-1 prototype at its headquarters in Denver, Colorado. The aircraft is a one-third-scale supersonic jet constructed as part of the development for the company's planned Overture supersonic passenger jet that's proposed to be rolled out by 2025.

2

1. XB-1's 21m-long fuselage has been optimally shaped for high-speed aerodynamic efficiency. The carbon-composite airframe maintains its strength and rigidity, even under the high temperatures and stresses of supersonic flight.

2. XB-1 is fitted with three J85-15 engines, designed by General Electric, which will provide more than 50,000 newtons of thrust, allowing the plane to fly at breakthrough supersonic speeds.

3. XB-1 will complete its ongoing, extensive ground test programme before heading to Mojave, California, in 2021 for flight tests.

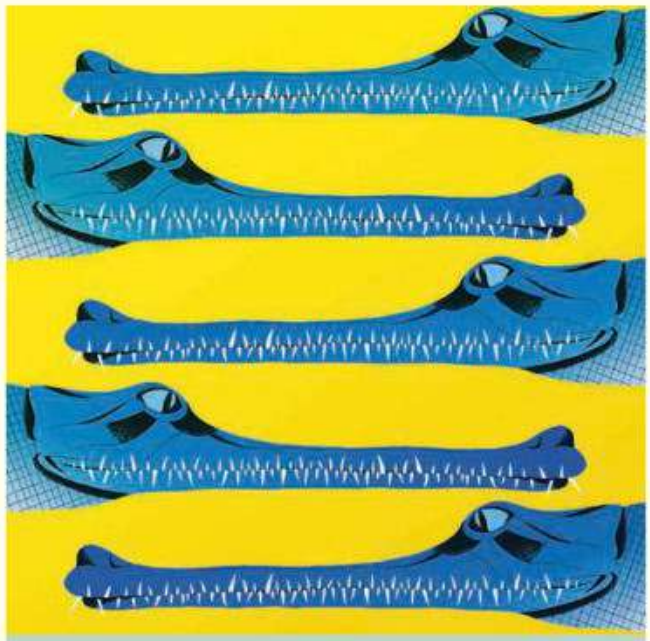
4. The delta wing balances low-speed stability at take-off and landing with high-speed efficiency when airborne. The aircraft's anti-skid brakes enable it to land safely at approach speeds of up to 340km/h.

3

BOOM SUPERSONIC X4

4

DRONE PHOTO AWARDS 2020



GHARIALS
Gharials are making a comeback in Nepal and India. They dwindled to just a few hundred in the early 2000s, but the designation of a stretch of the Gandak River as a reserve in 2018 has led to an uptick in numbers.

BIRDERS
In October, more than 140,000 red knots descended on RSPB Snettisham in Norfolk as part of their annual migration. A new record.

Good month

Bad month

CAT OWNERS
Diseases spread from cats to humans and livestock cost the Australian economy more than £3bn a year, according to a study by Australian National University in Canberra.

DIMLY LIT RESTAURANTS
A restaurant with mood lighting might be romantic, but it could make the food taste worse. A team at Maastricht University found that diners reported food as tasting more intense in brightly lit restaurants.

PALAEONTOLOGY

New species of Triassic marine reptile discovered that could float in water

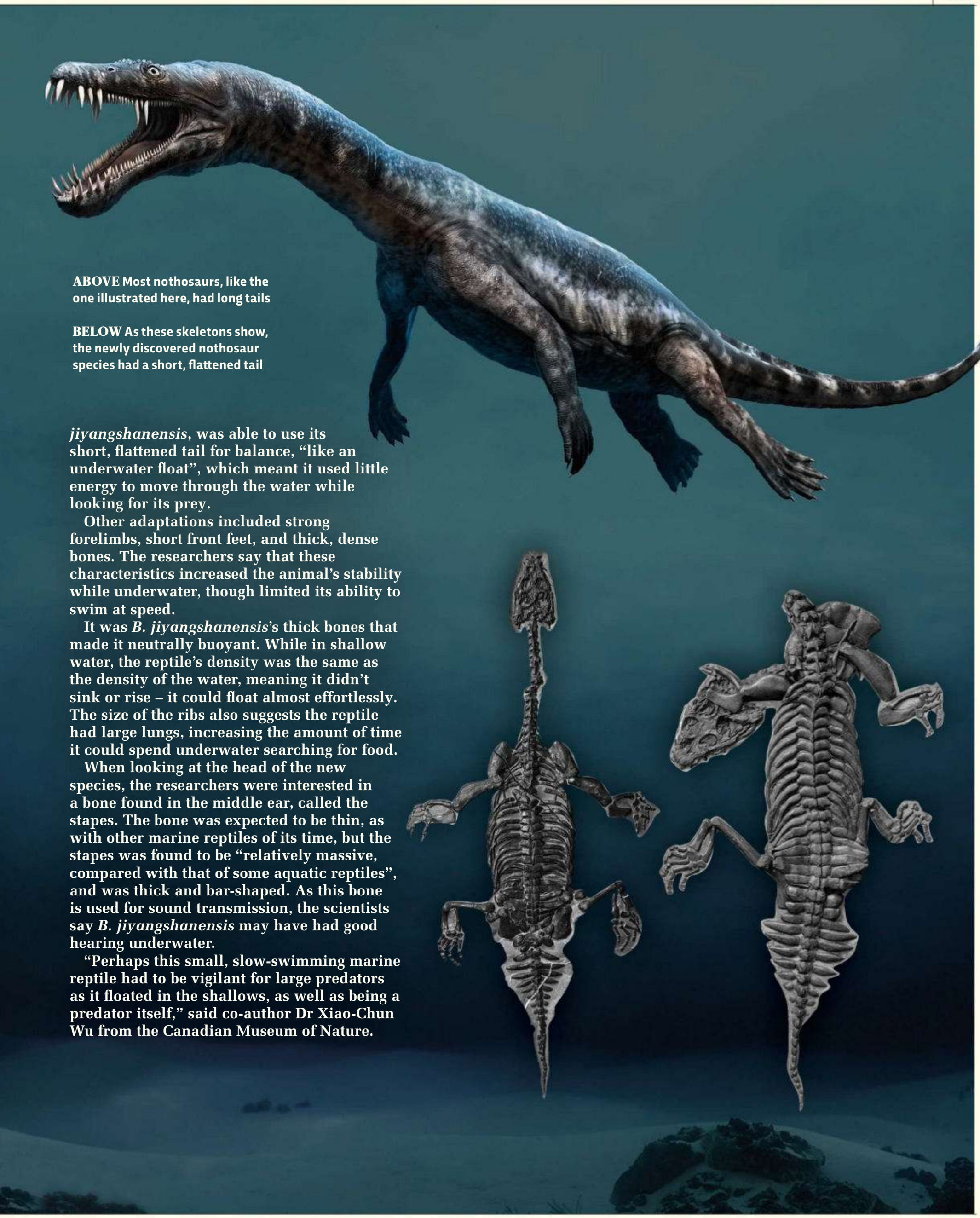
Analysis of two skeletons has revealed a new species of nothosaur – a group of reptiles that lived in the water during the Triassic period. The 60cm-long skeletons were identified as nothosaurs due to their small heads, wide snouts, long necks and flipper-like limbs, but researchers noted in their paper that the two specimens "differed from other known nothosauroids, mainly in having an unusually short tail".

"A long tail can be used to flick through the water, generating thrust, but the new species we've identified was probably better suited to hanging out near the bottom in shallow sea," said study co-author Dr Qing-Hua Shang, from the Chinese Academy of Sciences.

The newly discovered reptile, which has been named *Brevicaudosaurus*

"A long tail can be used to flick through the water, generating thrust, but the new species we've identified was probably better suited to hanging out near the bottom in shallow sea"

GETTY IMAGES, QING-HUA SHANG/XIAO-CHUN WU AND CHUN/JOURNAL OF VERTEBRATE PALEONTOLOGY ILLUSTRATIONS: CATHAL DUANE



ABOVE Most nothosaurs, like the one illustrated here, had long tails

BELOW As these skeletons show, the newly discovered nothosaur species had a short, flattened tail

jiyangshanensis, was able to use its short, flattened tail for balance, "like an underwater float", which meant it used little energy to move through the water while looking for its prey.

Other adaptations included strong forelimbs, short front feet, and thick, dense bones. The researchers say that these characteristics increased the animal's stability while underwater, though limited its ability to swim at speed.

It was *B. jiyangshanensis*'s thick bones that made it neutrally buoyant. While in shallow water, the reptile's density was the same as the density of the water, meaning it didn't sink or rise – it could float almost effortlessly. The size of the ribs also suggests the reptile had large lungs, increasing the amount of time it could spend underwater searching for food.

When looking at the head of the new species, the researchers were interested in a bone found in the middle ear, called the stapes. The bone was expected to be thin, as with other marine reptiles of its time, but the stapes was found to be "relatively massive, compared with that of some aquatic reptiles", and was thick and bar-shaped. As this bone is used for sound transmission, the scientists say *B. jiyangshanensis* may have had good hearing underwater.

"Perhaps this small, slow-swimming marine reptile had to be vigilant for large predators as it floated in the shallows, as well as being a predator itself," said co-author Dr Xiao-Chun Wu from the Canadian Museum of Nature.

PROF DAVID GRACIAS
Biomolecular engineer

Horizons

Parasite-inspired drug delivery system could be the future of medicine

The tiny, star-shaped 'theragrippers' latch onto the intestinal tract, to slowly release their drug payload

YOU BASED THE TECHNOLOGY ON PARASITIC HOOKWORMS. WHERE DID THAT IDEA COME FROM?

We've been trying to deliver drugs through the gastrointestinal tract, and that is a formidable challenge because the gastrointestinal tract has a mucosa – a mucus layer. It's kind of like a conveyor belt, it's constantly moving. It moves and it sheds [cells] in different parts at different rates.

We are used to using a patch for controlled release on the outside of the body, but if you put a similar patch on the inside it won't be retained. So, we were thinking, well, how does nature solve this problem? And we knew that there are worms and other organisms that colonise and live in the gastrointestinal tract for a long period. So, we started looking into them. They dig into the mucosa, so we had this new idea of doing that.

HOW BIG ARE THE THERAGRIPPERS AND WHAT ARE THEY MADE OF?

They are about a quarter of a millimetre, so barely visible to the human eye. And they are made out of metals and polymers.

HOW DID YOU CHOOSE THEIR SIZE?

We often optimise it, and it is dependent on the specific application. Larger sizes could potentially store more drug, but they become more invasive. People have made centimetre-scale devices, huge ones. But there's a risk of blockages and other issues, so smaller is less intrusive, in our opinion. But then we need more of them to achieve a specific quantity of drugs to be delivered.

HOW DO YOU GO ABOUT MANUFACTURING SOMETHING SO TINY?

We use similar processes to the microchip industry, so they are made on silicon wafer substrates. They are made using a process called photolithography, which is a standard workhorse in micro fabrication. And by doing so, we can make thousands of them at the same time on a wafer, which is what makes it cost effective.

ONCE A PATIENT TAKES THEM, HOW DO THE THERAGRIPPERS RELEASE THE DRUG?

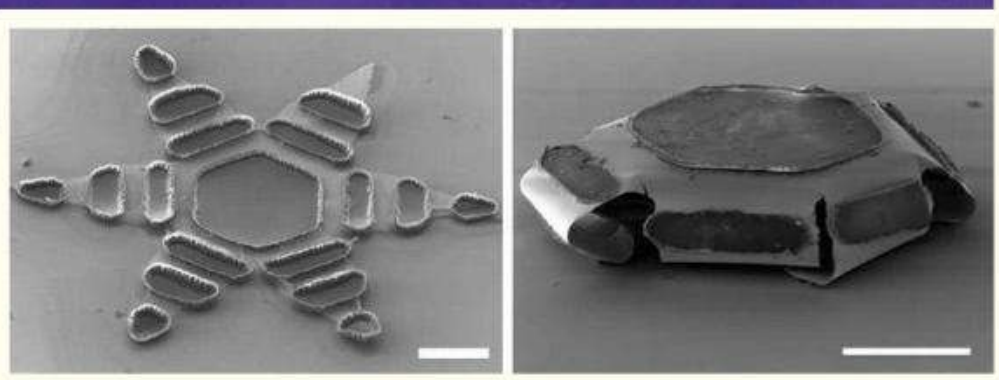
They can be taken either orally or through enema. The principle on which they work is like a loaded spring. Or you can think of it as a mousetrap. So, rather than a coiled spring, there are thin films that are under stress and they want to release. But the idea is the same.

We constrain them by using what we call a polymer trigger, and we work with different polymer triggers to make them so we can tune the polymer trigger to the environment around the gripper. So, for example, in this

SCIENCE PHOTO LIBRARY, JOHNS HOPKINS UNIVERSITY

"I'm definitely excited to be part of this vision for the future of medicine, which is this idea of advanced therapeutics"

The tiny theragrippers can be seen on this cotton bud as black specks



RIGHT On the left is an open theragripper primed to spring shut; the one on the right has closed up to grip the intestine and release its payload

present paper, we use a temperature-responsive trigger. We refrigerate them and then, because they are cold, the temperature trigger keeps them flat. In our animal tests, when they enter the body, they thermally equilibrate with the body, which is at a higher temperature of about 37°C or so, and that triggers them. In principle, you could trigger them by many different specific environments in the body, for example, pH or biomolecules.

ONCE THEY TRIGGER, HOW DO THEY ATTACH TO THE MUCOSA?

The theragrippers have claws and the claws release significant force and they attach. The drug is loaded on a patch [held inside] and it diffuses.

WHY IS IT SO IMPORTANT TO HAVE SYSTEMS THAT ARE SLOW RELEASE?

There are many motivating factors for sustained-release drug delivery. One of them is compliance. At the start of the paper, we talk about the annual waste of $600bn due to imperfect adherence to treatment. What that means is that if you get a condition and have to take medication, you may forget to take it or you may miss taking it, so compliance and adherence is hard and so that is one motivating factor. If you have a system that is continually releasing a drug then you don't need to take many doses.

The second one is that sustained release can maintain a uniform level of drug rather than having a lot of spikes, every time you take a pill, you get a jump, for example.

And the last one is that we live in a world where we want convenience and we want to not worry about these things. You can see that in products like the nicotine patch, for example, people just put it on and then they can forget about it for the rest of the day.

WHAT TYPE OF CONDITIONS COULD THERAGRIPPERS BE USED TO TREAT?

We are looking at a variety of applications. In our present demonstration, we used a painkiller, but we are looking at other drugs.

WHAT IS THE CURRENT STAGE AND WHERE YOU WOULD LIKE TO GO NEXT?

There's a lot of excitement in this new area of dynamic, smart machines and robotics. I'm definitely excited to be part of this vision for the future of medicine, which is this idea of advanced therapeutics. We coined this term 'active matter therapeutics', [to describe this new style of medicine] and I think that is going to be the dominant paradigm for the next few decades as we make medicine more efficient, safer, and more effective.

There are two avenues that we are trying to advance. One is the engineering side – we are looking at using capsules and putting them in other parts of the body. What sizes can we use? What drugs can we load? There's a lot of engineering research that we're planning. On the clinical side we would like to eventually advance this to humans. It's a big leap to go from the laboratory to the animal, which we did, but it's another leap to go from the animal to the human, mainly because of safety considerations.

My collaborator, Florin Selaru, is a practising gastroenterologist so this is a great partnership because I'm primarily coming from the engineering side but he's a medical doctor and actually does a lot of procedures with patients.

PROF DAVID GRACIAS
David is the director of graduate studies in the Department of Chemical and Biomolecular Engineering at Johns Hopkins University. ***Interviewed by*** **BBC Science Focus** ***commissioning editor Jason Goodyer.***

PCSPECIALIST

CUSTOM GAMING
DESKTOPS & LAPTOPS

CUSTOM BUILT TO YOUR SPEC

EASY TO USE CONFIGURATOR

CUSTOM PCS & LAPTOPS

AWARD WINNING SYSTEMS

COBALT PRO

Intel® Core™ i7-10700K
ASUS® TUF Z490-PLUS GAMING
16GB Corsair VENGEANCE 2666MHz
8GB GEFORCE RTX 2070 SUPER
256GB PCS 2.5" M.2 SSD
2TB SEAGATE BARRACUDA HDD
Genuine Windows 10 Home

This spec from
£1,541.99

OPTIMUS PRO

15.6" Matte Full HD 120Hz Screen
AMD Ryzen™ 7 Eight Core Processor 4800H
8GB Corsair 2400MHz DDR4
4GB GeForce GTX 1650 Ti
128GB ADATA SX6000 LITE M.2
Genuine Windows 10 Home

This spec from
£920.99

COBALT ELITE

Intel® Core™ i5-10600K
ASUS® PRIME Z490-P
8GB Corsair VENGEANCE 2400MHz
6GB GEFORCE GTX 1660 SUPER
256GB PCS 2.5" M.2 SSD
1TB SEAGATE BARRACUDA HDD
Genuine Windows 10 Home

This spec from
£934.99

ORDER ONLINE NOW AT

WWW.PCSPECIALIST.CO.UK

0333 011 7000

/PCSpecialist @PCSpecialist

GET A FURTHER £15 OFF WITH THIS EXCLUSIVE VOUCHER CODE: **BBF20**

* Prices are including VAT and are correct at the time of printing, but subject to change.

REALITY CHECK

SCIENCE BEHIND THE HEADLINES

Hedgehogs | K number | True COVID death toll

REVIEW

HEDGEHOGS: ARE THEY GOING EXTINCT IN THE UK?

Hedgehog numbers have sharply declined in the last two decades. Are they at risk of disappearing from the UK forever?

“A 2018 report estimated that over half of the hedgehogs in rural Britain, and a third of the urban ones, have gone since 2000 alone”

BBC

Visit the BBC’s Reality Check *website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

News stories about endangered wildlife have become sadly familiar, with many biologists now saying we are living through the planet’s sixth mass extinction because of the rate at which species are disappearing due to human activity. Recently, it was the hedgehog’s turn to make headlines. Having been assessed as vulnerable to extinction in the UK, the prickly insect-muncher was added to the Red List of Britain’s mammals, one of many official inventories of at-risk species produced by the International Union for Conservation of Nature (IUCN). Fortunately for the hedgehog, there is plenty we can still do to help.

COULD THE HEDGEHOG GO EXTINCT?

Unlikely. Conservationists working for the IUCN determine each species’ threat level according to specific criteria, and at the moment the European hedgehog, *Erinaceus europaeus*, is not endangered (in danger of vanishing in the wild). In parts of its huge range, which stretches east to forests around Moscow and south to the olive groves of the Mediterranean, it remains locally common.

But the species faces a growing number of severe threats. A 2018 report by the People’s Trust for Endangered Species and the British Hedgehog Preservation Society estimated that over half of the hedgehogs in rural Britain, and a third of the urban ones, have gone since 2000 alone. Such is the speed of this population decline, that the species meets the threshold for ‘Vulnerable’ status in the UK.

WHAT ARE THE MAIN THREATS?

Agricultural intensification since WWII has transformed vast swathes of land, removing the ‘patchwork quilt’ of hedges, woods and small fields in which hedgehogs thrive, and replacing it with huge, unvarying monocultures of cereal crops or chemically improved pasture. Insect numbers have crashed due to pesticide use, depriving hedgehogs of prey. Meanwhile, contemporary garden design does them no favours. Decking, patios, artificial turf, planters and a general obsession with tidiness in our manicured outdoor spaces – some conservationists wryly refer to this trend as ETD, or ‘ecological tidiness disorder’ – leave them without enough food and shelter. Another major cause of mortality is roadkill. A recent study by researchers at Nottingham Trent University suggested that up to 335,000 hedgehogs die on UK roads every year.

HOW CAN I MAKE MY GARDEN HOG-FRIENDLY?

The dramatic changes in farming practices mean that urban green space provides an increasingly important refuge for these charismatic creatures. You can help by gardening in a more hog-friendly way. Allow your lawn to grow longer (apart from being less work, it will also be more resilient to drought), let flowerbeds become messier, leave fallen leaves where they are and uncover any compost heaps (fertile foraging grounds for hedgehogs). Avoid using lawn feeds, weedkillers and slug pellets: the wilder and more natural your garden, the better. If you have a pond, add some stones or a ramp at the edge so hedgehogs can drink safely. Many custom-made hedgehog homes or ‘hogitats’ are now available, designed to accommodate their winter hibernation, but steer clear of anything expensive or twee. A pile of dry leaves, moss, straw and sticks under bushes in a quiet part of the garden can be equally effective.

WHAT DO THEY EAT?

Hunting mainly by smell, hedgehogs sniff out a wide range of invertebrate prey, from beetles and bugs to earwigs, woodlice, earthworms, millipedes, slugs, snails and various insect larvae. They love caterpillars and the larvae of craneflies (daddy longlegs), which burrow in soil. Given the chance, hedgehogs will snaffle birds’ eggs ➲

BELOW Thousands of hedgehogs die on the UK roads every year

GETTY IMAGES X2

"The hedgehog's enduring popularity could prove to be its saviour"

in summer, as well as windfall fruit. Hedgehogs are natural pest controllers, beneficial to gardeners and farmers alike.

Although a wild-foraged diet suits hedgehogs best, there's no harm in putting out a small bowl of natural food such as dried mealworms, or meat-based cat or dog food. Never offer milk, as hedgehogs are lactose intolerant. Carbohydrate-heavy bread, pizza and biscuits, which have limited nutritional value, are another no-no. Supplementary food is most useful in late summer and autumn, when hogs are fattening up prior to hibernation. You may also attract foxes, and that's fine – research into fox-hedgehog interactions by the University of Brighton shows that these mammals usually co-exist in gardens.

WHAT ELSE CAN I DO TO HELP?

Hedgehogs wander up to two kilometres a night in search of food and mates, so need access to large areas of connected habitat. The suburban maze of gardens divided by countless impenetrable fences and walls is therefore bad news, but a simple fix is to create CD-sized holes at ground level, enabling them to roam at will. Almost a million people have signed a petition asking the UK Parliament to make these hedgehog highways a requirement in all new housing developments. The hedgehog's enduring popularity – it won a 2013 poll to find Britain's favourite wild animal by a landslide – could prove to be its saviour. If you're worried about a hedgehog, visit **britishhedgehogs.org.uk** for advice.

by **BEN HOARE** *(@benhoarewild)*

Ben is editorial consultant at BBC Wildlife Magazine. *His latest wildlife book for children is* Wild City *(£12.99, Pan Macmillan).*

ANALYSIS

THE K FACTOR: NEVER MIND THE R VALUE, HERE'S THE NUMBER WE NEED TO UNDERSTAND TO DEAL WITH COVID-19

The R value, which reflects how infectious COVID-19 is, has stolen all the headlines. But there's another measure that could help us better understand how the virus spreads and how we can stop the pandemic

ABOVE The R number tends to drop if people wear masks, maintain social distancing, and wash hands regularly

GETTY IMAGES

Over the course of the pandemic, scientists have been gathering data about the coronavirus to inform mathematical models and predict the spread. Statisticians assign values to the parameters within which a disease is transmitted. Many of us have heard of the reproduction number, or the R number, of the coronavirus. It tells us, on average, how many people one infected person will pass the disease on to.

The R number changes depending on the circumstances. If people remain socially distant and wash their hands frequently, the figure tends to drop. Without these measures, it seems that the natural R value of COVID-19 is three: one person, on average, passes the disease on to three more.

If we can get the R number to below one, the virus will spread to fewer and fewer people and eventually stop transmitting completely.

So, why are regions with R numbers close to one still seeing a rise in coronavirus cases? Throughout the pandemic, scientists have been gathering data about the coronavirus to inform mathematical models and predict the spread. As they've done so, the understanding of the virus's transmission has improved.

"R is a really easy number for people to grasp," says Benjamin Althouse, an epidemiology research scientist at the US-based Institute for Disease Modeling. "But it washes over the people who spread a lot, or those who spread very little."

Research has shown that as much as 80 per cent of transmission events come from just 10 per cent of all infected individuals. This means that most people with COVID-19 don't seem to pass it on. It was thought to be the same with previous outbreaks of the SARS and MERS coronaviruses, with most cases coming from so-called super-spreader events.

Take the example of South Korea's Patient 31. This person attended several church services in February before testing positive for COVID-19. These events are now thought to have started more than 5,000 cases. More recently, in the US, Dr Anthony Fauci called the unveiling of President Donald Trump's nominee to the Supreme Court a super-spreader event after 11 people in attendance tested positive.

With information about a virus's transmission, statisticians are able to calculate a dispersion value: the K number. This can be any number up to infinity. The larger the number, the more consistency there is in the way a disease spreads. The smaller the number, the more it seems that transmission is caused by a few individuals. The K number for SARS-CoV-2 is around 0.1. The SARS 2003 coronavirus has a similar K number of 0.16, while the number for measles is 0.22. A study in Switzerland looked at seasonal influenza and found a wide range of K values depending on the year, ranging from 2.36 to 53.18.

Althouse explains COVID-19's dispersion using the analogy of starting a fire. Imagine a pile of logs. Lighting a match and flicking it onto the pile might not set the wood alight. Doing the same with a second match still might not work. But the third match could bring the whole pile to flames. "Now think about dropping someone infected with COVID-19 into a room," says Althouse.

Identifying the conditions that make the virus overdispersed is key to the fight against COVID-19. To take the above analogy further, understanding that a wet pile of logs will take longer to light, or that a larger match introduces a larger flame, will help inform policies and public messaging to keep transmission down.

Quentin Leclerc, a PhD student at the London School of Hygiene & Tropical Medicine, is one of the authors of a paper outlining the settings thought to foster super-spreader events.

"We found that the environments where most of these events happened were indoors, where people were in close proximity to one another, where there was little ventilation, and where people tended to speak loudly," says Leclerc. But, as Leclerc points ➲

ABOVE If someone was infected with COVID-19 at a particular location, chances are other people would have caught it there too

out, there is a bias when it comes to identifying where someone might have picked up the virus.

"If you ask someone who's been infected to recall the contacts that they've had, they're more likely to remember when they've been indoors with other people. They're not going to remember that one contact when sitting next to a stranger on a bench in the park."

Leclerc says that's why it's not a good idea to try to rank these settings. "What matters are the characteristics of these settings. Take two restaurants: they're not going to have the same risk because one may have people are seated outside, while the other is intimate and poorly ventilated."

Understanding this should inform contact-tracing efforts, says Leclerc. Currently, if a person tests positive, the UK government website says that NHS Test and Trace "helps trace close recent contacts" and "if necessary, notifies them that they must self-isolate at home to help stop the spread of the virus". This is called forward contact tracing – trying to stop the virus from moving forward and infecting others.

"Because of the dispersion value, the chances that an individual has infected other people is actually pretty low," says Leclerc. "But if you go back one step and try to look at where they were infected, chances are other people were also infected at that setting."

Another aim of the study was to identify settings which governments or public health institutions should consider keeping closed, or keeping a close eye on, when lifting full lockdown restrictions.

For Althouse and Leclerc, it's important to say that transmission is mainly caused by super-spreader events, not super spreaders. Research has shown that individuals can be infectious in the days leading up to their first symptom, which means they could spread the virus without even knowing they've got it. "It's not malicious," explains Althouse. "We all need to be extra careful in our actions."

by AMY BARRETT

Amy is the editorial assistant at BBC Science Focus.

ANALYSIS

COVID-19: HOW SHOULD WE COUNT DEATHS?

How can we calculate the true toll of the pandemic?

As the number of COVID-19 deaths worldwide surpasses one million and continues to climb, the real number could be much higher due to misclassified and indirect deaths.

At the beginning of the pandemic, information about rates of infection, hospitalisation and even deaths was often delayed or unreliable. Testing was not widely in place and the understanding of the biological and clinical features of the virus made classifying a 'COVID death' difficult.

As many countries are facing a second wave of COVID-19, monitoring has also entered a new phase with more robust data and better reporting systems. However, there are still many cases that may slip through the cracks.

"We will never know the exact number of COVID-19 deaths simply because many patients will never be tested, even though they die from COVID-19," says Dr Lasse Vestergaard. Vestergaard is a medical doctor and epidemiologist who coordinates EuroMOMO, which provides real-time mortality monitoring for 26 European countries. "With the estimation of excess deaths, however, we have a quite precise picture of the total mortality burden from COVID-19 and how it affects different populations," he adds.

So how do you calculate the toll of the COVID-19 pandemic? One method is by looking at 'excess deaths'. Networks like EuroMOMO collect data on the number of people who have died from all causes and compare that to the average number for previous years. The difference in deaths is considered 'excess deaths' and gives a better measure of how many people actually died during the pandemic. Excess deaths have been used in the past to measure the impact of swine flu, seasonal influenza and natural disasters.

In a recent paper published in *Nature Medicine*, researchers looking at 19 countries in central and western Europe, Australia and New Zealand, found that more than 200,000 additional people died in the first wave, when compared to how many deaths would be expected without a pandemic. The death rate was about 30 to 45 per cent higher than average in the hardest hit countries – England and Spain.

SCIENCE PHOTO LIBRARY, GETTY IMAGES

"We will never know the exact number of COVID-19 deaths simply because many patients will never be tested, even though they die from COVID-19"

A separate report published in the journal *JAMA* showed there were 225,000 excess deaths in the United States between March and July. Of those, about two-thirds could be explained by COVID-19, which left 75,000 deaths unaccounted for. While the numbers vary between countries, there is often a significant gap that remains.

INDIRECT DEATHS

There are many people who are victims of COVID-19 even if the virus is not what ultimately kills them. COVID-19 puts a significant strain on health services and many people could die of chronic diseases when they would not have otherwise, explains Magali Barbieri, associate director of the Human Mortality Database. These patients may succumb to a disease early because they were weakened by an infection, hospitals were too full or they chose to delay treatment.

In a paper published in the medical journal *The Lancet*, researchers forecasted that disruptions to HIV, tuberculosis, and malaria programmes in low- and middle-income countries could have an effect comparable to direct COVID-19 deaths over the next five years.

Barbieri notes there are also more indirect effects related to 'the social and economic fallout' of COVID-19. In the United States, there have been reports of an increase in opioid-related deaths over the last year which, she says, could be related to people feeling too isolated or a lack of resources. Economic hardship could potentially lead to indirect deaths from a number of causes such as addiction or people not being to access the help they need, especially in countries without universal healthcare.

It's too early to tell what the true toll of the pandemic will be from both direct and indirect deaths. While current reporting systems can give a real-time picture of deaths, it may take years to accurately analyse COVID-related deaths. The 'gold standard' is to use data from the vital statistics system in each country which has a detailed breakdown of cause of death and contributing factors, but this information may not be processed on a global scale until 2022.

ABOVE Even people who have never caught COVID-19 can become indirect victims of the virus

SILVER LINING

Researchers and health officials have moved quickly to improve reporting systems and decrease the delay in data. These real-time monitoring systems helped to expose weaknesses in the healthcare system, assess the effectiveness of COVID-19 interventions and could help detect the next public health crisis.

Counting deaths can be morbid, but it's also hopeful, says Dr Steven Woolf, a professor of family medicine and population health at Virginia Commonwealth University who authored the *JAMA* paper on excess deaths in the US. For Woolf, how policymakers act on COVID-19 death data today will determine how the next chapter of the pandemic unfolds.

"We have examples of countries, and specific states [in the US], that have demonstrated an ability to bend the curve and get the numbers back to normal," he says. "States that took this more robust response had a much more successful story." SF

by **JUANITA BAWAGAN**

Juanita is a freelance science writer.

CHRISTMAS GIFT GUIDE

If Christmas is cancelled, it might be the best thing that's ever happened to Christmas. No more cross-country drives, no more sleeping in your childhood bedroom and no more sharing the TV remote. Instead, we recommend you treat yourself to one of these gifts, and if you really have to, we suppose you could send someone a voucher or something…

Lumie Halo

With daylight hours dwindling, the Lumie Halo could be just the ray of sunshine you need. In 'day mode', it boasts 10,000 lux, which is the recommended intensity that may improve seasonal affective disorder (SAD). It's easy to set up, unobtrusive, and has made my dingy, north-facing home office feel much more bearable. And when I'm up against a deadline and working late, I switch it to the sunset-like 'evening mode', which reduces the amount of blue light.

£199, LUMIE.COM

Herman Miller x Logitech G Embody Gaming Chair

Working from home has left me with the posture of a melted candle. To rescue my back, I'm considering a new office chair and this reinvention of the 'gaming' chair by Herman Miller, an office furniture designer with a collection of iconic pieces to its name, is at the top of the list. The design throws out the 'it's just been pulled out of a boy racer's Citroen Saxo' aesthetic that's usually associated with anything made for gamers, and opts for a breathable, curved piece that supports your spine along its full length.

£1,195, LOGITECHG.COM

Mario Kart Live: Home Circuit

This new take on *Mario Kart* looks so much fun that I'm considering having kids, just so we can play it together. *Mario Kart Live* gives you the kit to turn your living room floor into a race circuit. You then pilot a remote-controlled kart via your Nintendo Switch, which provides you with a cockpit view direct from the kart's camera. Here's the twist: augmented reality tech overlays Mario Kart's usual cocktail of chaos – mushrooms, shells and banana skins – on the real world. Here's the catch: you'll need at least two Switches and two karts to have any real fun.
£99.99, NINTENDO.CO.UK

Mattel The Child Real Moves Soft Toy

Star Wars fans young and old, and most of the internet along with them, are besotted with this little walking turnip from the *Star Wars* TV series *The Mandalorian*. This scale animatronic toy is remote controlled via a wrist strap 'tracker', a replica of the device used by the show's villains to track down the little critter. The Child will plod about, gurgle and coo, and force murder others when threatened, just like in the show.
£60, SHOPDISNEY.CO.UK

Sony XB01

Need a last-minute stocking filler? You couldn't do much better than this dinky Bluetooth speaker from Sony. The XB01's build is optimised to boost its bass, delivering punchy sounds – there are no tinny vocals here. There's a line-in and USB socket for wired input, and Sony says the speaker will play for six hours continuously before needing a recharge.
£30, SONY.CO.UK

Alessi Plico

Okay, so you're going to have to have been EXTRA good this year to deserve this, but we can dream can't we? There probably isn't a piece of furniture better suited to turning your living room into the home office it's likely now become. The Plico, a reissue of a creation by industrial designer Richard Sapper whose work is now on display in the MoMA, is a folding trolley that acts as a laptop desk by day and drinks trolley by night, which is exactly the sort of thinking we're going to need to get us through this pandemic.

£900, ALESSI.CO.UK

Patagonia Nano Puff

Forecasters are predicting a bitter winter. Patagonia's Nano Puff is one of the best ways to keep the cold at bay and it's just got even better. The newest version uses 100 per cent recycled insulation, which means the entire jacket is now made of recycled material. The coat is designed to be an all-rounder, breathable but sturdy enough to shield you from the wind or a rain shower. When there's sunshine (remember that?) it packs down to the size of a travel pillow.

£180, PATAGONIA.COM

Apple Watch SE

We've grown to love Apple's smartwatch, and the new budget iteration, the Watch SE, is no different. The fitness tracking is intuitive and intelligent, recognising when you're working out and what you're doing. It's waterproof too, so it'll follow you into the pool or out in the wild. There's Apple's fall detection inside as well, alerting emergency contacts or the authorities if it detects a fall or a seriously abnormal pulse.

Apple has introduced family mode too, so you can give one to the kids, *sans* iPhone. They can use them as walkie-talkies, to send texts, play music and call you via the watch. Plus Apple Fitness+ is on the horizon, which will beam fitness classes to your phone while keeping an eye on the metrics provided by your watch.

FROM £269, APPLE.COM

BOOKS

EXPLAINING HUMANS: WHAT SCIENCE CAN TEACH US ABOUT LIFE, LOVE AND RELATIONSHIPS

DR CAMILLA PANG

Looking for a way to navigate her life as an adult with ADHD and autistic spectrum disorder, Dr Camilla Pang found concepts in science that could help explain social phenomena – how fear can be broken down into something manageable is reflected in the way that light refracts through a prism, for example. Accessible scientific explanations are combined with engaging anecdotes to create a manual for understanding humans.

YOU'RE NOT LISTENING: WHAT YOU'RE MISSING AND WHY IT MATTERS

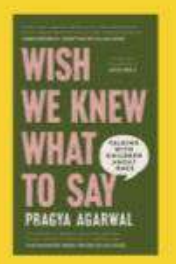
KATE MURPHY

When was the last time you went into a conversation expecting it to go one way, only for it to be derailed? Kate Murphy has spent years listening to people, from scientists to prisoners, and priests to party-goers, getting to the heart of their story. *You're Not Listening* is her guide for better communication. At a time when our interactions are limited, it's even more vital to listen to each other, and be listened to.

HUMANKIND: A HOPEFUL HISTORY

RUTGER BREGMAN

Some accounts of human history are filled with war, conflict and despair. While these tales offer us lessons for the future, there is another way to learn from our mistakes, says historian Rutger Bregman. Despite what some believe, he says people are inherently good. We are not naturally selfish, nor are we fundamentally evil, and he provides examples from science, literature and history that show why we should be hopeful, even in this trying time.



WISH WE KNEW WHAT TO SAY: TALKING WITH CHILDREN ABOUT RACE

PRAGYA AGARWAL

From a data and behavioural scientist, this book gives parents the confidence to answer their children's questions about race and racism. It includes questions, resources and suggestions for scenarios that could start these tricky conversations, written with delicacy and authority. This isn't just for parents, though, it's aimed at anyone who has young people in their life and wants to support the education of the next generation.

THE END OF EVERYTHING: (ASTRO-PHYSICALLY SPEAKING)

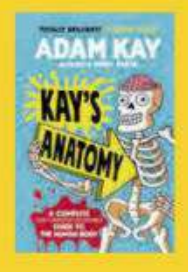
DR KATIE MACK

A book about the end of the world might not appeal at first, but this witty wander through cosmology is a strangely refreshing read. Cosmologist Dr Katie Mack explains major concepts from across the sciences that reveal what we do and do not know about our Universe. From string theory to quantum mechanics, this is an accessible guide to the five ways that astrophysicists think the Universe could end.

THE RULES OF CONTAGION: WHY THINGS SPREAD – AND WHY THEY STOP

DR ADAM KUCHARSKI

How do mathematicians build models that predict pandemics? What does data tell us about public health? And how can studying the spread of 'fake news' inform our understanding of virus transmission? There have been a lot of virus-related books this year, and although this one was written by mathematician Dr Adam Kucharski before the pandemic, it is the essential guide to understanding contagious diseases.



KAY'S ANATOMY: A COMPLETE (AND COMPLETELY DISGUSTING) GUIDE TO THE HUMAN BODY

DR ADAM KAY

From the doctor who wrote the bestselling memoir *This Is Going To Hurt* comes a tour through the body. *Kay's Anatomy* is like a *Horrible Histories* for the human body, answering questions like: What's in a bogey? Do hideous creatures really live on our eyelashes? How does food become poo? Probably best to have your Christmas dinner before opening presents, if you intend on gifting this one...

ENCYCLOPEDIA PREHISTORICA: SHARKS AND OTHER SEA MONSTERS

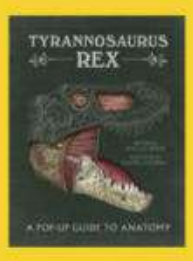
ROBERT SABUDA AND MATTHEW REINHART

These often-forgotten prehistoric monsters once ruled the seas, and they are no less menacing in their pop-up paper form. A fight between two sea lizards unfolds between the pages, and the tentacles of ancient squid reach out from the depths of the ocean. Stunningly crafted and meticulously researched, *Encyclopedia Prehistorica* is a book that will be used and admired again and again.

VOYAGE THROUGH SPACE

KATY FLINT AND CORNELIA LI

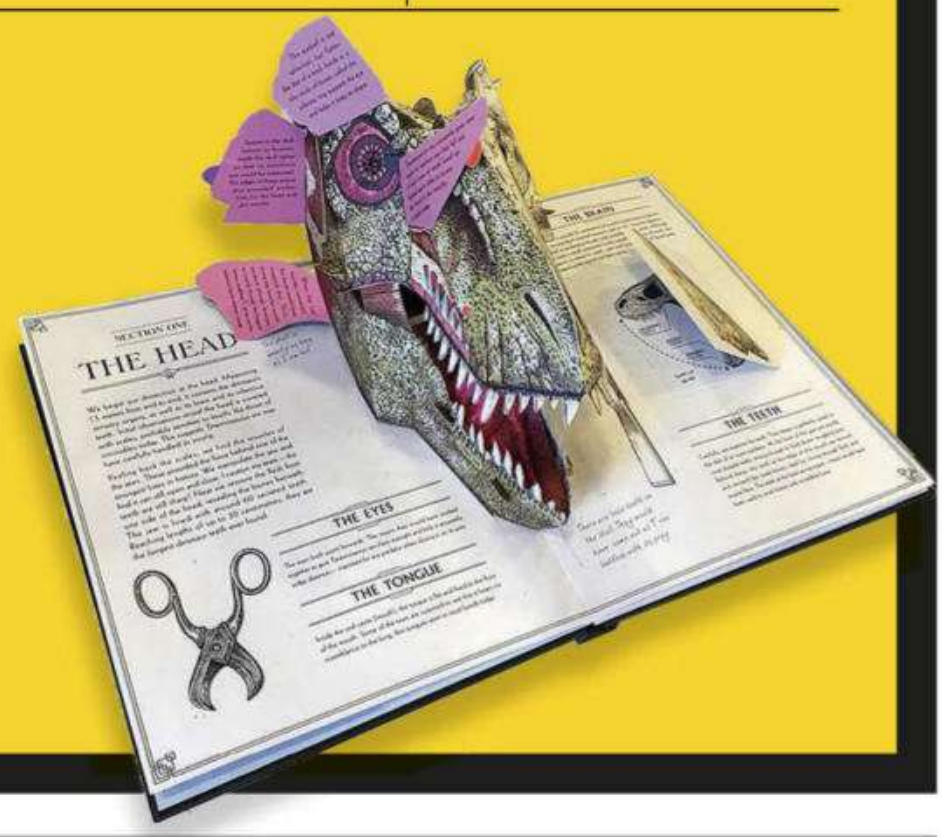
Lights out for this bedtime story, as a glow-in-the-dark adventure through space is about to begin. In their exploration of the Solar System, one astronaut and her dog encounter everything from the fiery solar flares that leap from the Sun's surface, to the icy cold objects that make up the Kuiper belt. You'll want to look at the book in the daylight, too – not just to 'recharge' the glowing effects but to admire the beautiful illustrations of the cosmos.



TYRANNOSAURUS REX: A POP-UP GUIDE TO ANATOMY

DOUGAL DIXON AND RACHEL CALDWELL

Opening this book is like beginning a dinosaur dissection. Page by page, layer by layer, the *Tyrannosaurus rex* is brought to life. The stunningly intricate details are accompanied by facts about the dinosaur, as well as the mysteries that remain unsolved. The *T. rex*'s head leaps from the page, then a slice of its cheek peels back to reveal the muscle underneath, while the sections of its skull are labelled and explained. It's aimed at children, but you might find you want to keep it for yourself...



Dyson Lightcycle Morph

When the days are short and the nights are long, good lighting can help keep you sane. Dyson's Lightcycle Morph is perhaps the ultimate work light: as the day gets darker the LED bulbs inside get brighter, maintaining a consistent ambient light level while you work. The smart hinges and joint means you can point the light anywhere, and you can adjust the warmth and intensity of the light for different moods like 'precision' and 'relaxation'. Set it to 'synchronised' mode and the LEDs inside will adapt, whether it's pointed down at the desk or upwards towards a wall. The net result is that you'll feel more alert, and certainly experience less eye strain if you work in front of a monitor all day.
£499.99, DYSON.CO.UK

Belkin Boost Charge 3-in-1 Wireless Charger Special Edition

Liberate your desk or nightstand from a tangle of charging wires with this wireless charger designed for Apple devices. It can power up an iPhone, Apple Watch and earpods all at once, and manages to look remarkably smart when not in use. If you're not an Apple devotee, Belkin has a range of equally handsome wireless chargers for Android devices.
£99.99, BELKIN.COM

Yeelight Stario Bedside Lamp Pro

This wonderfully simple design hides a smart little light. The lamp itself can connect to your smart home kit, whether that's controlled by Alexa, Siri or Google, letting you turn it on, adjust the brightness and warmth and set timers via your smartphone. This means you can also programme certain scenarios, like setting the lamp to an hour-long timer when you've sat your phone on the wireless charging point hidden in the base.
FROM £55, YEELIGHT.COM

Bang & Olufsen Beolit 20

I love the new Beolit 20 from Danish audio brand Bang & Olufsen. With its cutesy picnic basket handle, the Bluetooth speaker is designed to picked up and taken with you around the house, lasting around eight hours between charges. And with three full-range speaker drivers and a big subwoofer inside, this portable speaker system should be a room filler. There's a wireless charging pad at the top for juicing up your smartphone's battery. Get two, and you can pair them together to create a stereo sound system.
£450, BANG-OLUFSEN.COM

Philips Momentum 278M1RY

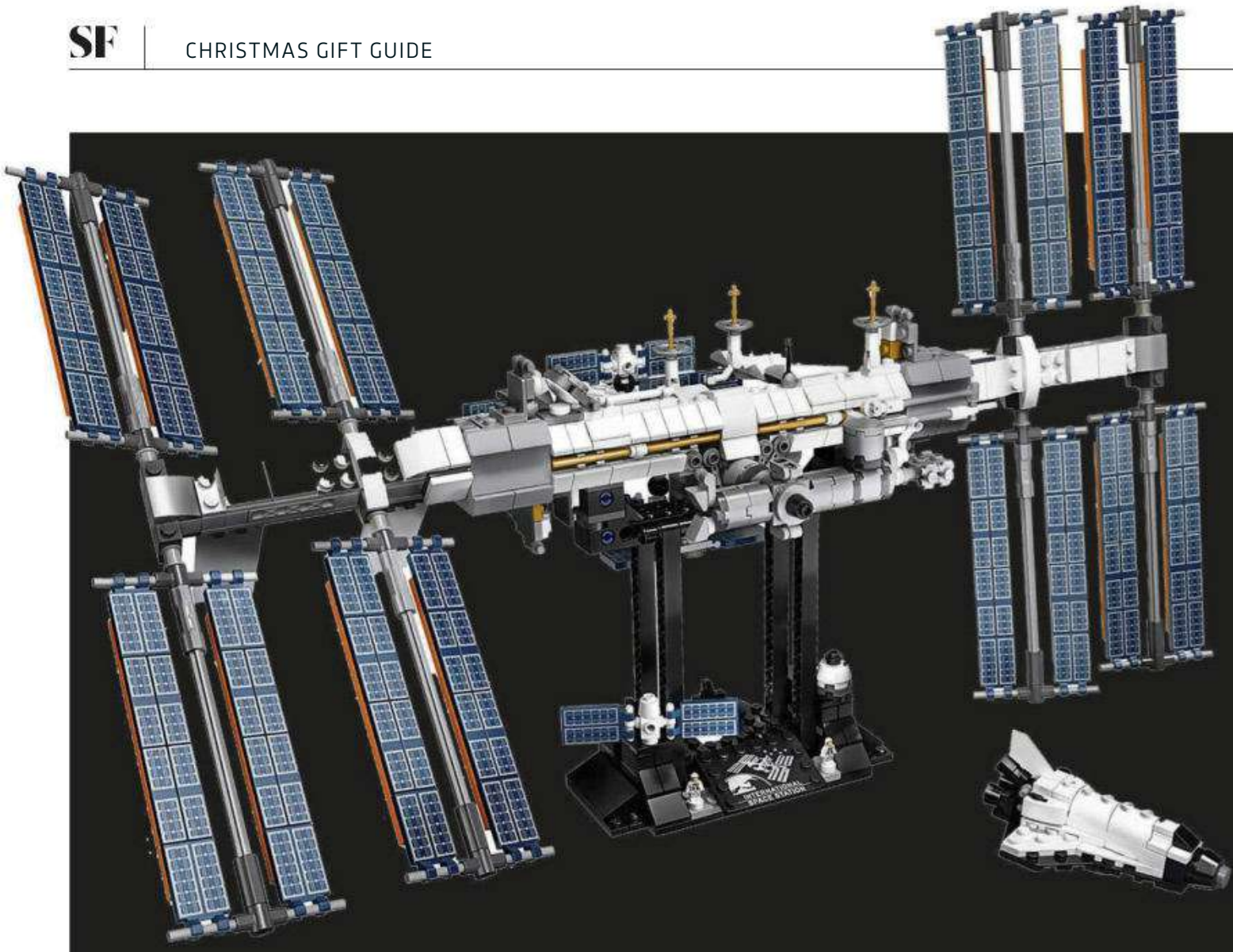
Philips is bringing its atmospheric Ambiglow tech to a new range of gaming monitors. Ambiglow creates a halo of light around your monitor, amplifying what's on the screen by beaming the colours at the edges of the display outwards into the room. On a desktop monitor, this trick is not that useful when editing spreadsheets or composing emails, but it really transforms your office space into a gaming room by night. Plus, the display is ultra-HD and HDR-ready, with a fast response time to reduce input lag – particularly useful in games that require fast-twitch responses.
£399, PHILIPS.CO.UK

Hario V60 coffee drip scale

One for the coffee obsessive – you know, the kind that doesn't put sugar in their hot drinks. Hario's pour-over coffee kits are the best, inexpensive way to make a decent cup of joe without breaking into a coffee shop. Now, you can get a Hario weighing scale with built-in timer, which means you can tinker with your brew by adjusting how much ground coffee you put in (to 0.1g accuracy) and how long you brew it for. Then, when you're dialled in, you can recreate the perfect cup every time. It gets bonus points for looking like something *Breaking Bad*'s Heisenberg might have in his kitchen.
£65, HARIO.COM

Lego Star Wars Mos Eisley Cantina

Has there ever been a string of words more likely to get people of a certain age checking their bank accounts? While I can't condone spending this much on Lego, my heart says otherwise. There are 21 minifigures included – three of which have never been released – and the entire 3,187-piece set spans 52 x 58cm when fully built. Created for what Lego calls the "discerning hobbyist", this set is strictly for adults… which is just as well, considering what's about to happen to Ponda Baba.
£319.99, LEGO.COM



Lego International Space Station

For something that won't leave you wincing at your bank account balance, there's the much more sensible Lego recreation of the ISS, which celebrated 20 years of carrying passengers in low-Earth orbit this year. The 864-piece set includes a teeny-tiny Space Shuttle, a pair of gold-visored astronauts and a stand for displaying it.
£64.99, LEGO.COM

Apple iPhone Mini 12

5G is going to take off in 2021 and the iPhone Mini is potentially our favourite phone to take advantage of the huge speed boost the new network will provide. As part of its new 5G range, Apple has shrunk its flagship model – the iPhone 12 – to create the Mini, which is a smaller, lighter phone that you won't need Shrek-like hands to navigate. Plus, Apple's shaved £100 off the price, without cutting any of the features included in its bigger sibling. This includes a ceramic shield, which Apple says offers four times more fall protection than any smartphone glass, the new, ultra-powerful A14 bionic chip and a camera that's better equipped for night-time photos.
£699, APPLE.COM

Marshall Emberton

Everyone makes a portable Bluetooth speaker these days, but Marshall's nostalgically styled Emberton is one of our favourites. It's not much bigger than tin of beans, but it pumps out a big, bassy, room-filling sound. It looks best nestled next to some books on a shelf, but it's light (700g), waterproof (IPX7 rating) and offers 20 hours of playtime between charges, so it's equally at home in the great outdoors.
£129.99, MARSHALLHEADPHONES.COM

Sony WH-1000xm4

Lockdown has left me with a new appreciation for peace and quiet. Short of duct taping two pillows my head – which I haven't ruled out – a comfortable pair of noise-cancelling headphones is the best way to find some zen. These headphones are my pick. Sony's brilliant noise-cancelling tech frees your ears up to listen to the deep, warm, voluminous sound produced by the internal chip that also contains a DAC (digital-to-analogue converter) and an analogue amplifier. The end result is a generous sound that feels like you're in the room with your favourite artist.

FROM £350, SONY.CO.UK

Bang & Olufsen Beogram 4000c Turntable

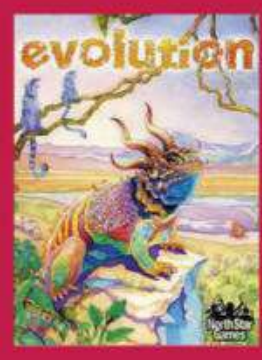
Bang & Olufsen is delving into its design archive and modernising some of its most cherished products. First up is this record player rebuilt piece by piece with modern materials and electronics. There'll only be 95 units available, and with a spendy price of £9,000, we don't think Santa will be dropping one down our chimney any time soon. Sure is nice to look at though…

£9,000, BANG-OLUFSEN.COM

BOARD GAMES

PANDEMIC

Okay, so 2020 might not be the best year to recommend *Pandemic*. But despite the subject matter, it's great fun, and it's refreshing to play cooperatively with your friends rather than against each other. Together, you travel the world, suppressing four diseases and sharing knowledge. Between the epidemics and the threat of running out of time, it often ends with a nail-biting race to the finish.



EVOLUTION

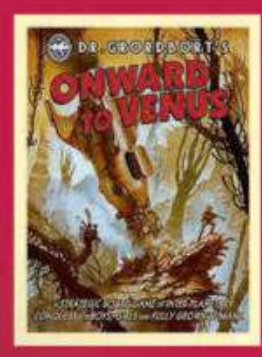
Hard shell, long neck or an ambush predator? Your goal is to give your species useful traits so they will thrive. The points system is based on the total amount of food that your species eats, which is a measure often used by biologists to quantify the success of a species. Just try not to get too attached to your creatures, as the threat of extinction is never far off.

COMPOUNDED

In this game, you play as a lab manager, racing your rivals to synthesise chemical compounds. Each compound is represented with a card showing its name, structure and state of matter, and you can claim those points once you've collected the necessary elements. Keep track of your score on a periodic table as you trade with rivals and hurry to finish your compounds before a lab explosion!

LOVELACE & BABBAGE

In this quickfire game, you play as a 19th-Century computing pioneer to programme the Analytical Engine. Your goal is to complete tasks using the Engine and your character's abilities. A bit like the numbers round in *Countdown*, you perform mathematical operations to reach targets and win points. As the game goes on, you unlock more complicated operations to earn extra points.



ONWARD TO VENUS

Play as a 19th-Century colonist in the steampunk world of the Dr Grordbort graphic novels. Your targets are the planets and moons of the Solar System. Claim resources, attack other players and go hunting. Be careful: if you don't keep good control of your colonies, each planet and moon could have its own potential crisis, from a robot uprising to space pirates. Grab your ray gun and go!

POWERING THE HOME *of the future*

Smart meters are here, and they will change everything… including your **electricity bill**

Today we have smart security systems to help keep our homes safe and smart voice assistants to help with household tasks, but there's one part of the smart home that's poised to really change our lives: smart energy. And the first step towards this future is having a smart meter installed in your home at no additional cost.

Smart meters are replacing our analogue energy meters just as smartphones replaced our rotary telephones. A crucial cog in the wheel of creating a cleaner, greener, smarter and more secure energy system for the entire nation, the smart meter gives us the tools to control and manage the energy use in our homes and on a national scale.

At first this will happen thanks to an in-home display (IHD) that tracks energy expenditure in near-real time so we can respond and adjust our habits. But as the technology matures, smart meters will allow our internet-connected fridges, washing machines and heating systems to talk to our energy suppliers to decide when it's most efficient to run, benefitting both our pockets and the planet.

This will mean that rather than relying on old-fashioned timers or rushing home at lunchtime to put a wash on when energy is cheaper, we'll be able to let our homes decide when to do that hot wash, based on when the smart meter tells it energy is the cheapest.

"Smart meters will help our energy system more efficiently match supply and demand," says Robert Cheesewright of Smart Energy GB. "That's the big challenge we face in trying to get to energy net zero because we have variable demand." This technology – known as Demand Side Response – leverages the communication abilities of a smart meter to allow for 'Time of Use' tariffs, setting lower prices when lots of supply is being generated and then telling those smart appliances about it.

In this future, an energy-efficient home with an electric vehicle in the garage, an electric heat pump powering the central heating, and smart, wi-fi connected appliances doing the housework could leverage the connectivity of a smart meter and adapt all its requests for energy from the grid in relation to the current supply and demand.

> **"The combination of batteries and smart meters means it's possible to use cheap or free energy to power your home"**

Another key component in the smart energy system are batteries. Batteries could one day be common in homes as a way to store excess energy generated by personal solar or wind power and as a place to store cheaper energy to use when prices are higher.

Cheesewright uses the common kettle as an example. "In the future, if you've got a kettle with a battery in it, you could boil water when energy is cheap and then use the energy stored in the kettle to have another cheap cup of tea later, when energy is more expensive," he says.

Similarly, using the smart meter's connectivity technology coupled with a smart off-peak tariff from your supplier, your electric vehicle could determine the optimal time to charge in order to get the best value.

A smart energy system equipped with batteries can also save energy and make you some money. At times of peak demand, the grid can essentially buy back some of your stored energy – whether it's in your electric car or wall mount – reducing the need for extra energy generation while slashing your personal bills.

But the benefits of batteries in our home will be more than just energy savings. They will also be there as a back-up, providing energy for your home in the event of an outage. This is because batteries can also store electricity imported from your energy supplier (known as brown electricity), so if the power goes out, you can simply flick a switch and the lights will come back on.

When your home is powered by this type of smart energy system – where your smart appliances and vehicles can talk to your energy supplier and get you the best deal and your home can power itself thanks to stored electricity in batteries – then we'll really be living in the home of the future. And all you need to get started is a smart meter.

See for yourself

Sometimes, the numbers speak for themselves. Here's some important stats you need to know about smart meters.

We could achieve

11%

of the UK's **2050 carbon emissions target** just by taking household energy efficiency measures.

64%

of people with smart meters feel more in control of the energy they use at home.

Britain could save a total of **£5.6bn** on energy bills in the next 20 years.

If every UK household took action on energy efficiency now, we could save up to **54 million tonnes** of carbon dioxide.

The smart meter in-home display, allowing you to track your energy expenditure in near-real time

Contact your energy supplier now to request a **smart meter** installation

Eligibility may vary

Smart Meters
Join the quiet revolution

UNIVERSE, SAY CHEESE!

IN A CALIFORNIA LAB, SCIENTISTS AND ENGINEERS ARE PUTTING THE FINISHING TOUCHES TO A COLOSSAL CAMERA THAT COULD CHANGE THE WAY WE VIEW THE COSMOS

WORDS: ROBERT BANINO

JACQUELINE ORRELL/SLAC

Pictures help us make sense of the world around us. From cave paintings, doodles and diagrams, to maps, sketches and photographs, as our tools for depicting the world have improved, so too has our understanding of it. And the device you see on these pages might be the most advanced picturing tool yet. It's the focal plane of the Legacy Survey of Space and Time (LSST) Camera, and is the biggest and most sophisticated piece of photography equipment on – or off – the planet. It's being developed at the SLAC National Accelerator Laboratory in California for one of the most ambitious astronomy surveys ever undertaken.

"It's going to be a 10-year survey," says Prof Aaron Roodman, the scientist in charge of the camera's assembly. "We're going to take ➲

ABOVE A mosaic of 189 image sensors has been used to create the LSST Camera's focal plane, which breaks records for both its size and picture resolution. It measures 64 x 64cm and contains 3.2 billion pixels

images of every part of the southern hemisphere sky that's visible from a mountaintop in Chile. And we're doing that to enable a whole host of science projects."

The LSST Camera won't just be obtaining a handful of images, though. It'll be taking around 1,000 every night. And the images will be big. The LSST Camera's focal plane is 64 x 64cm, giving each image a 9.6 square degrees field of view – enough to contain 40 full moons. Each of the image sensors in the LSST Camera is 40 x 40mm and 189 of them have been tiled together to create the focal plane. To put that in perspective, a typical DSLR camera uses a single 36 x 24mm image sensor.

But the size and number of images aren't the only staggering things the LSST Camera will provide. The detail in the images will be unprecedented too, because the focal plane contains 3.2 billion pixels. When it's eventually installed in the Simonyi Survey Telescope (itself an equally extraordinary device constructed around a gargantuan 8.4m-diameter primary mirror) at the Vera C Rubin Observatory in Chile, it'll be capable of detecting light from objects too dim and distant to otherwise be seen.

ALL-SEEING EYE

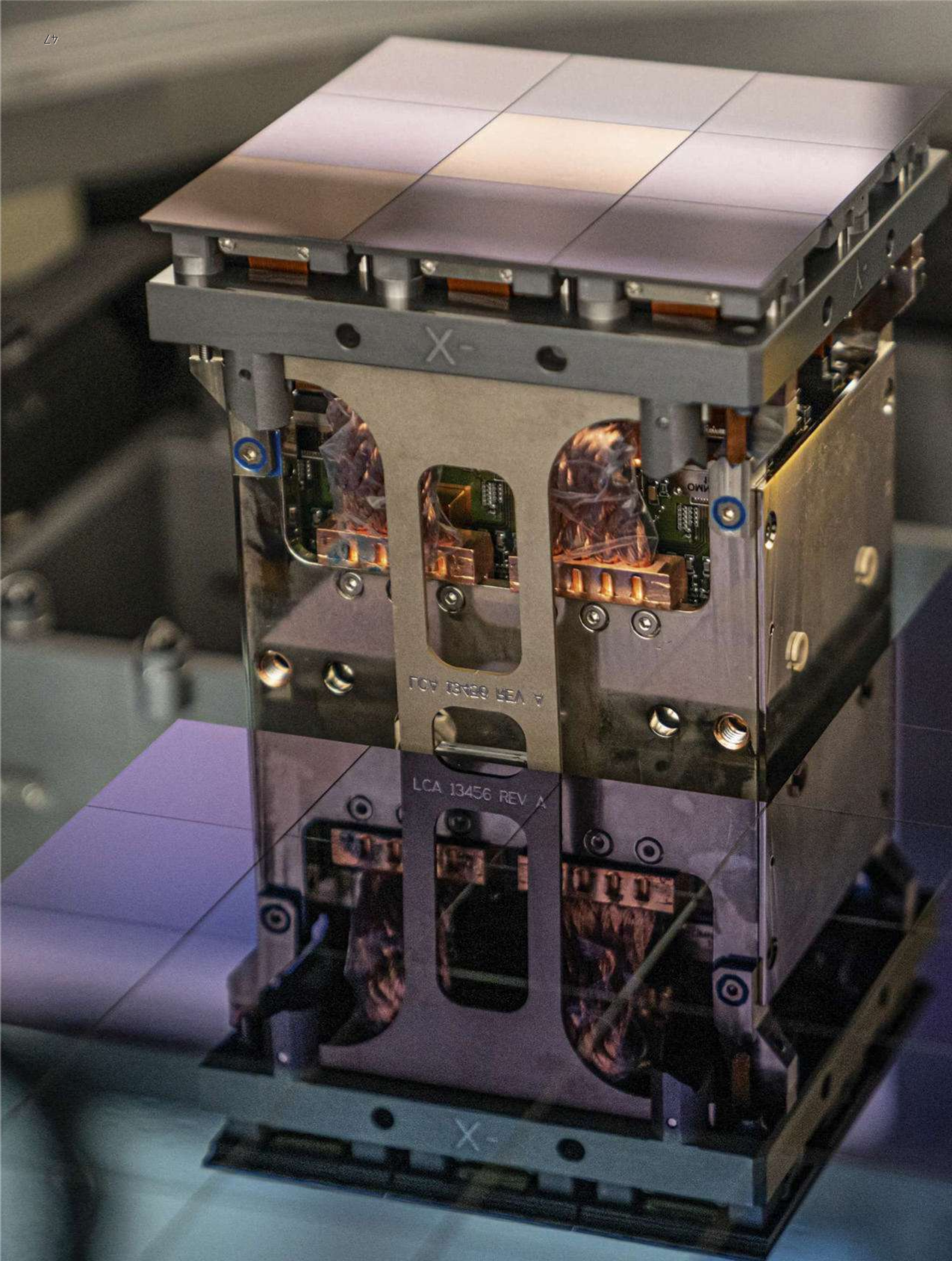
During its decade-long survey, the LSST Camera will picture more of the sky in more detail than ever before.

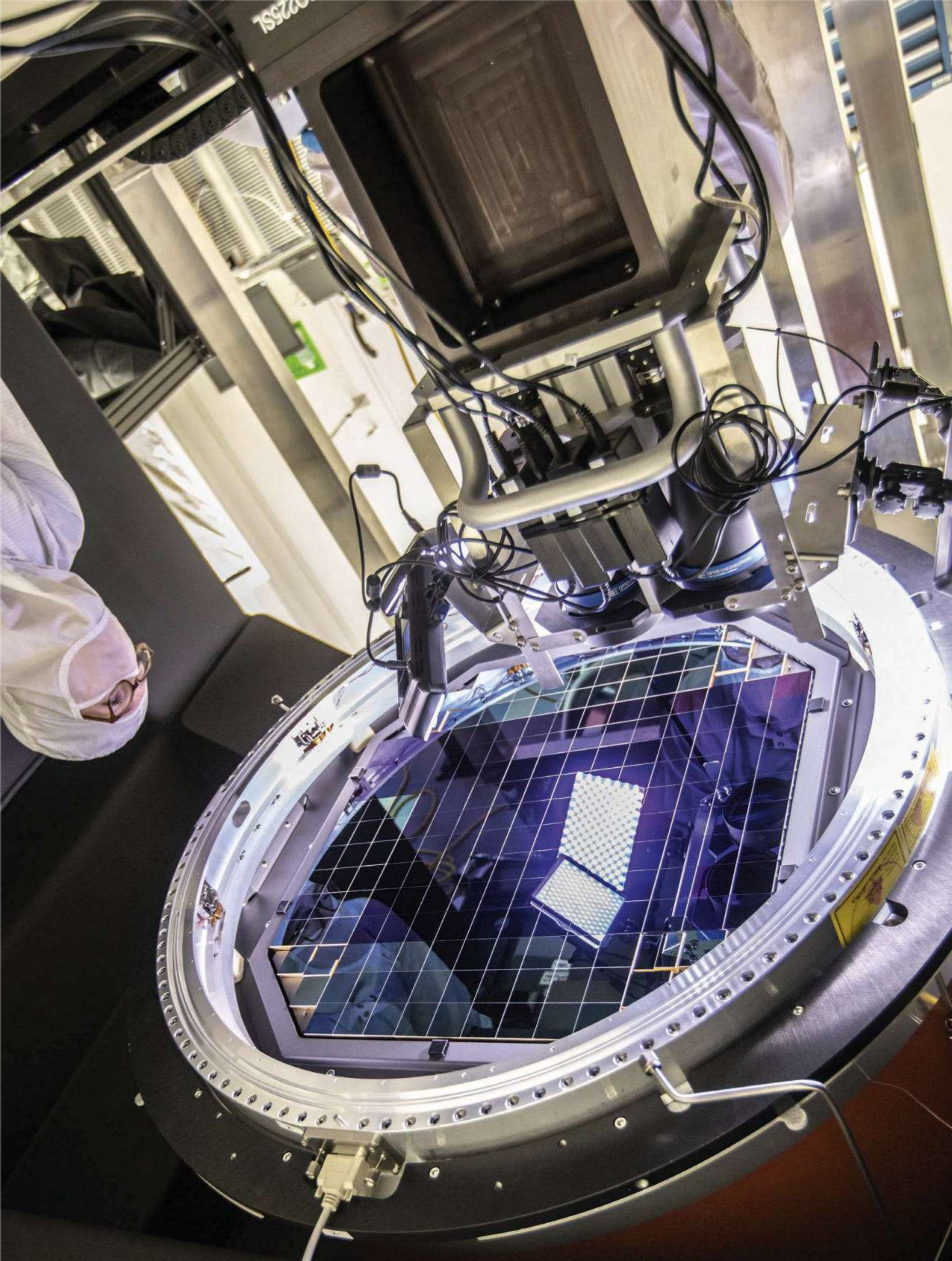
"We're going to see 20 billion galaxies," says Roodman. "We'll also be able to study our Galaxy, the Milky Way, in incredible detail. We'll observe billions of stars and get information about how far away they are and whether they're moving. We'll also study the Solar System…

ABOVE Engineers in a clean room at the SLAC National Accelerator Laboratory in California monitor and control the custom-built machinery and software used to carefully construct the focal plane

RIGHT The focal plane is made of 21 'rafts', each containing nine 40 x 40mm image sensors and costing around $3m (£2.3m approx). To ensure the focal plane catches as much light as possible, the gaps between rafts are less than 0.5mm

JACQUELINE ORRELL/SLAC


X-
LCA 13456 REV A
X-



We expect to see millions of objects. If Planet Nine exists, we have a good shot at seeing it."

Everything the LSST Camera spots will be studied and used to produce a new catalogue of astronomical objects, which will be the most comprehensive to date. But, as Roodman explains, the aim isn't only to produce a bigger and more thorough picture of the objects in the Universe: it's also to show us how those objects change over time.

"The fact that we'll take images of the sky so fast and repeatedly means that we can study time-variable phenomena in a totally new way. No one has really done that before. [Previous] surveys have typically only looked at the sky a few times. So a project [that pictures it 1,000 times a night] really is ground-breaking," Roodman explains.

By enabling us to monitor the way in which objects change, the LSST Camera should give us a new window on the fundamental nature of the Universe. In particular, the 95 per cent of it we can't see that's made up of the mysterious entities known as dark matter and dark energy.

Dark matter doesn't absorb or reflect light, but there's so much of it that it has gravity. And that gravity is enough to distort the light from objects around it, changing their appearance or making it look as if they're in a different place. The LSST Camera will detect these distortions and use them to map the distribution of dark matter.

Dark energy is another mystery and, since it makes up almost 70 per cent of the Universe, has bigger implications. We know very little about dark energy other than that it's causing the Universe's expansion to accelerate, contrary to our understanding of it.

The LSST Camera will allow scientists to precisely measure the gaps between galaxies and gauge how those gaps have grown, hopefully shedding new light on the dark energy that continues to make them grow.

SPANNERS IN THE WORKS

Building a device with such capabilities is not an easy task. Leaving aside the telescope that it'll be attached to, the LSST Camera alone contains over 5,000 parts, many of which are custom-made, excruciatingly expensive and packed into an uncomfortably tight space. So, needless to say, the focal plane's construction was nerve-racking and carried out with extreme caution.

The focal plane was finished in January 2020 and since then has been undergoing testing and fine-tuning. The COVID pandemic halted progress for a couple of months, but it's underway again now and it's hoped the completed LSST Camera will be ready to be shipped to Chile in 2021 before the survey begins in 2022.

But COVID isn't the only problem facing the project. The team says that the growing constellation of Starlink satellites belonging to Elon Musk's SpaceX company threatens its potential for breakthrough observations.

The satellites are intended to provide high-speed internet access across the globe. To do that they must fly in low-Earth orbits and be highly reflective, giving each satellite the potential to blaze a broad and bright streak across the LSST Camera's images.

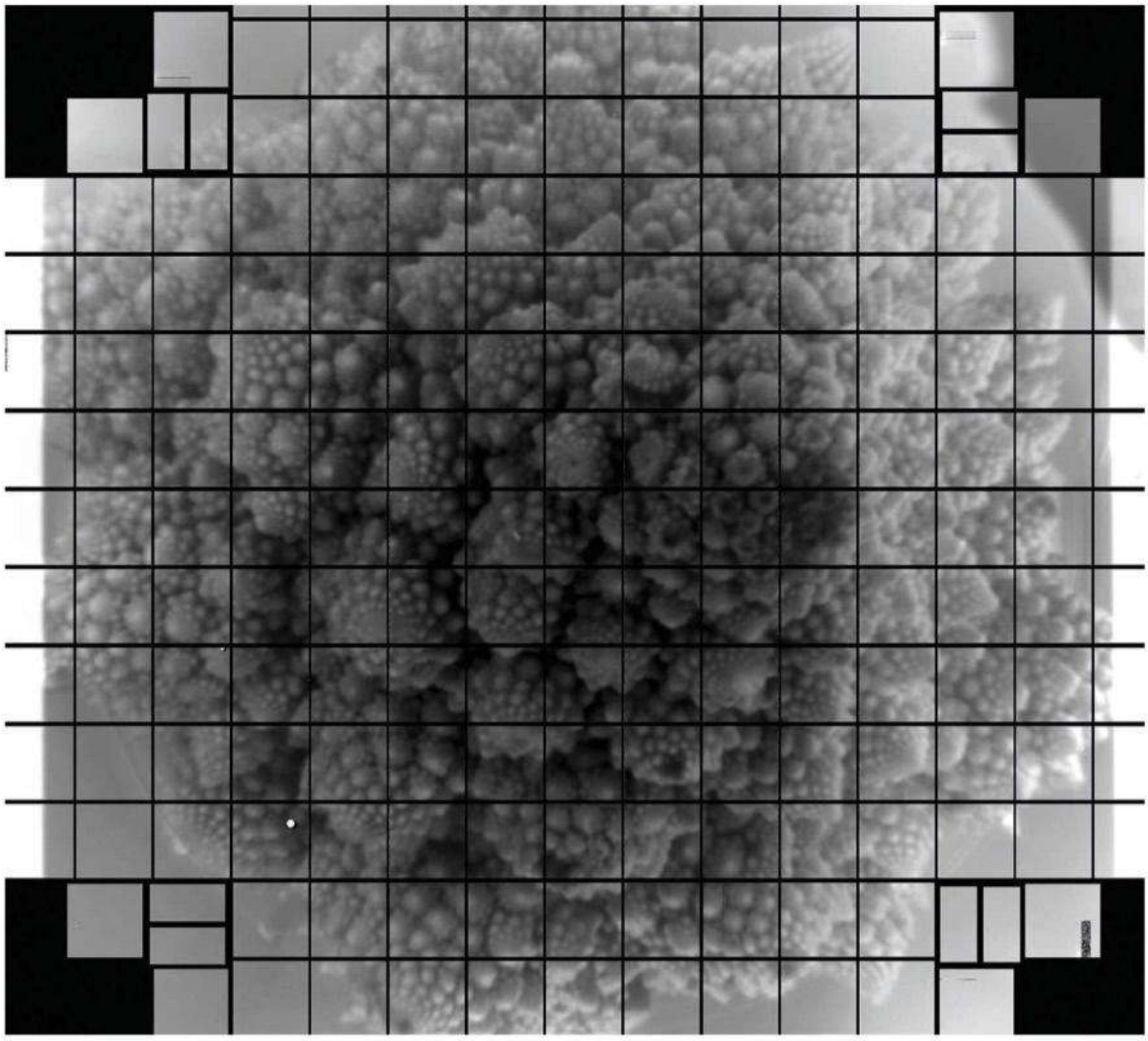
Given how far into the depths of space the camera will be looking, any obstructions in the foreground will hide a lot of detail in the distance. A single satellite could obscure a

"PREVIOUS SURVEYS HAVE TYPICALLY ONLY LOOKED AT THE SKY A FEW TIMES. SO A PROJECT THAT PICTURES IT 1,000 TIMES A NIGHT IS GROUND-BREAKING"

LEFT As well as being extremely close together, the image sensor rafts also have to be very precisely aligned. The surface of the focal plane varies by less than one-tenth of the width of a human hair

ABOVE Sophisticated hardware and software enables the vast amount of visual data the focal plane catches to be processed phenomenally fast. Its 3.2 billion pixels can be read out in just two seconds

JACQUELINE ORRELL/SLAC



LEFT A head of Romanesco broccoli was among the first items used to test the capabilities of the LSST Camera. Each of the fractal vegetable's smaller buds mimics the larger ones, giving it an abundance of detail that shrinks progressively down to tiny scales

BELOW The Romanesco sits inside the pinhole projector built to project test images onto the focal plane. Other test items included an image of Vera C Rubin, a key figure in the discovery of dark matter, after whom the observatory in which the LSST Camera will be housed is named

number of distant objects, and the Starlink constellation will contain thousands of satellites, not to mention the thousands more that are set to be launched by other satellite internet companies.

It's a huge concern for Roodman and everyone involved in the project. "At best it's going to be a serious nuisance and at worst it'll really impact our observing," he says.

"We've been working with SpaceX to let them know what we need and they've done some things to darken the satellites. I believe one or two of the darker satellites are up now but the brightness hasn't dropped as much as we'd like."

While Starlink and similar satellites don't throw the entire project into jeopardy, in their current form they curtail its ambitious potential. Even so, the picture of the Universe that the LSST Camera gives us will still be bigger than anything before. Maybe not as big as it could have been, but big enough to possibly change our understanding of the cosmos. **SF**

JACQUELINE ORRELL/SLAC

by **ROBERT BANINO**

Robert is a freelance science journalist based in Bristol.

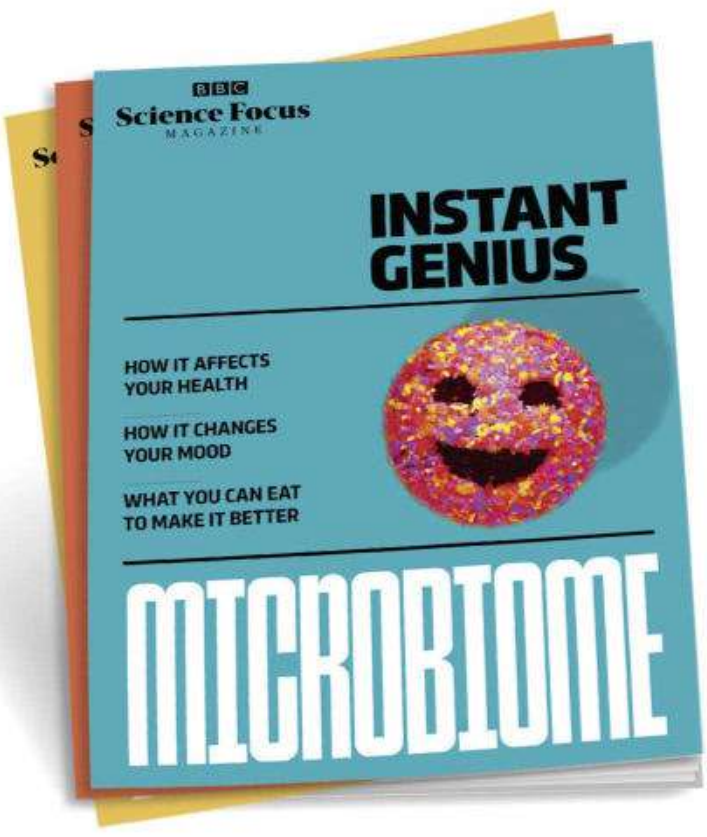
FROM THE MAKERS OF

BBC Science Focus

A daily dose of mental refreshment delivered straight to your inbox

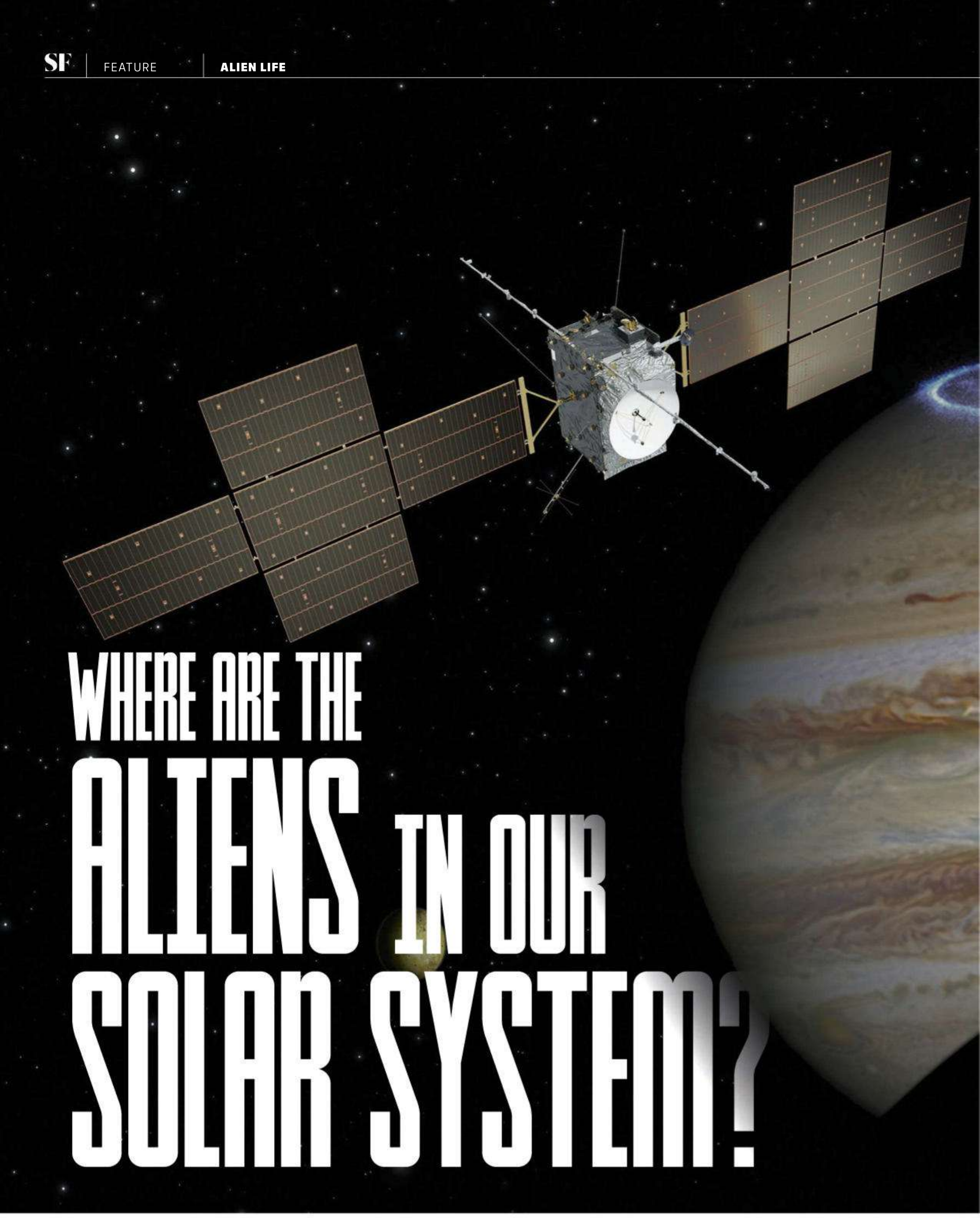
Sign up to discover the latest news, views and breakthroughs from the *BBC Science Focus* team

www.sciencefocus.com/newsletter


BBC Science Focus MAGAZINE
INSTANT GENIUS
HOW IT AFFECTS YOUR HEALTH
HOW IT CHANGES YOUR MOOD
WHAT YOU CAN EAT TO MAKE IT BETTER
MICROBIOME

PLUS FREE MINI-GUIDE EVERY WEEK

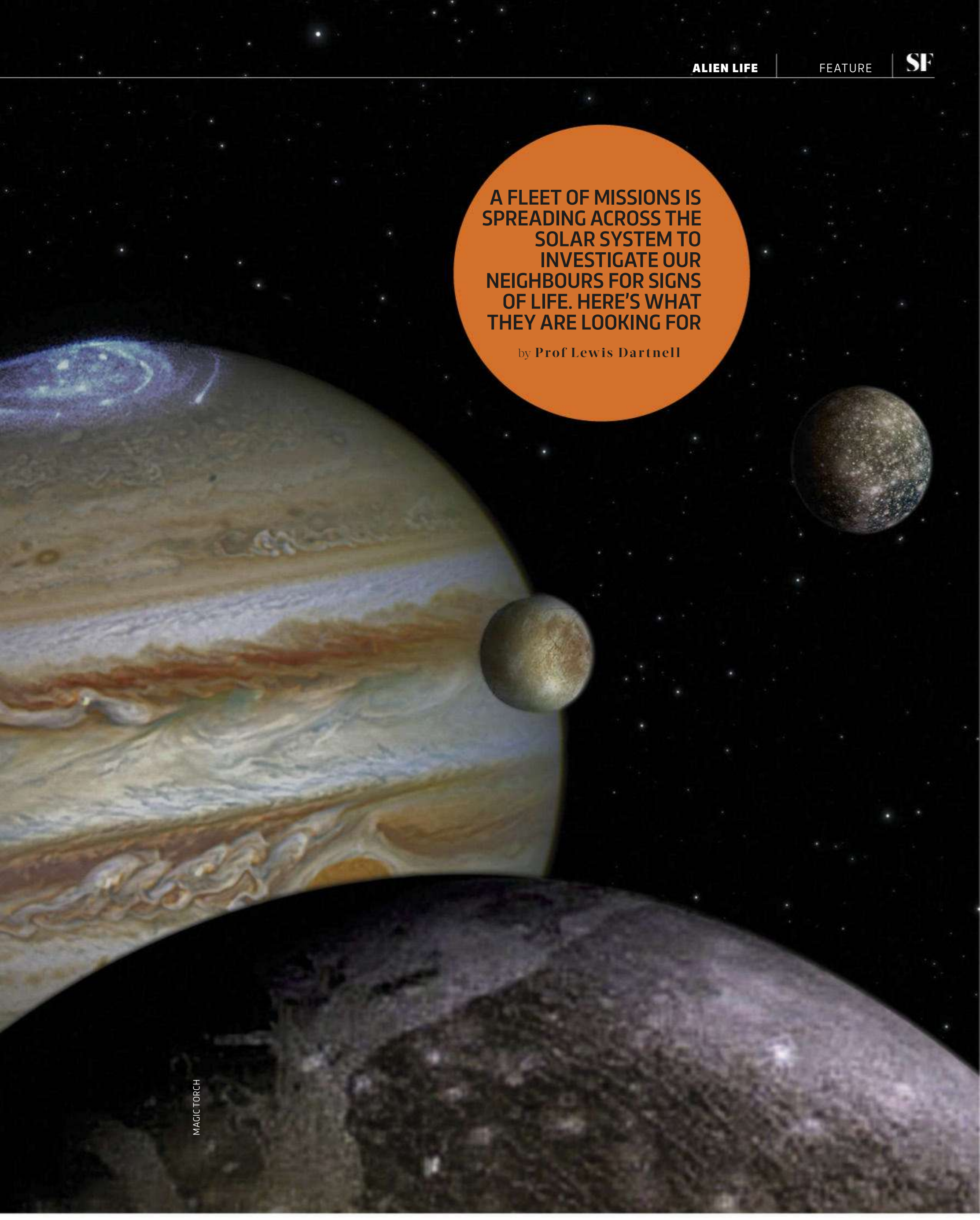
A collection of the most important ideas in science and technology today. Discover the fundamentals of science, alongside some of the most exciting research in the world.



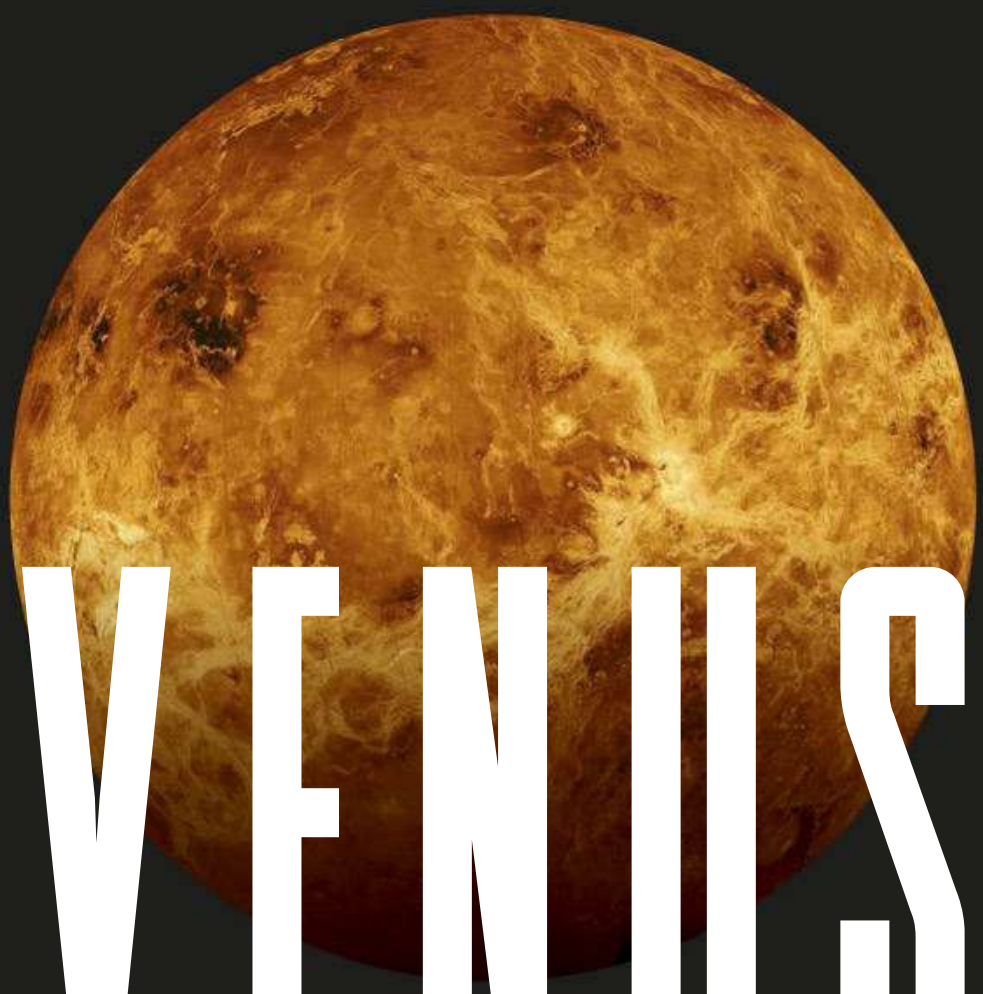
WHERE ARE THE ALIENS IN OUR SOLAR SYSTEM?

A FLEET OF MISSIONS IS SPREADING ACROSS THE SOLAR SYSTEM TO INVESTIGATE OUR NEIGHBOURS FOR SIGNS OF LIFE. HERE'S WHAT THEY ARE LOOKING FOR

by **Prof Lewis Dartnell**



MAGIC TORCH



VENUS

LOCATION: 108 MILLION KILOMETRES FROM THE SUN
PROS: MAY HAVE HARBOURED OCEANS FOR A LONG TIME
CONS: HELLISHLY HOT ON SURFACE, CLOUDS OF CONCENTRATED SULPHURIC ACID
MISSIONS PLANNED: DAVINCI+ (2026 LAUNCH, NOT CONFIRMED)

NASA, MIT, SCIENCE PHOTO LIBRARY, ESO

You'd have to have been living under a rock on a distant planet to have missed the news this September about the unexpected – and as yet unexplained – discovery of the gas phosphine in the atmosphere of Venus. By October, there were some doubts creeping in about whether phosphine had really been detected, but either way there's definitely some previously unknown chemistry going on in the Venusian atmosphere. Perhaps it could even be *bio*chemistry – is the phosphine be a telltale signature of Venusian life?

The problem with Venus, at least for astrobiologists, is that it's a truly hellish world. The planet is smothered in an exceptionally thick atmosphere of carbon dioxide, which creates a powerful greenhouse effect. The surface temperature is over 460°C: hot enough to melt lead. As you rise to higher altitudes the temperature grows cooler (just as experienced by mountain climbers on Earth), and by around 55km the temperature and pressure are similar to Earth's surface: T-shirt weather. But the droplets making up the clouds here are concentrated sulphuric acid – far more extreme than could be survived by any hardy life known on Earth. Perhaps Venusian life – if it exists – evolved to tolerate much higher acidities than us wimpy terrestrials, and migrated up into the cloud layer from ancient oceans before the planet underwent its runaway greenhouse effect.

But no matter how unlikely the prospect of life in an aerial biosphere on Venus might be, the discovery has certainly stoked interest in the further exploration of the planet. Luckily there's already a mission being considered by NASA's Discovery Program. DAVINCI+ was shortlisted at the beginning of the year, and if selected could launch as early as May 2026. The mission will release a probe into the Venusian atmosphere that will take measurements with its sensitive spectrometer instruments as it parachutes down. Dr Melissa Trainer, a space scientist at the NASA Goddard Space Flight Center, helped propose DAVINCI+. "Finally we'll get a clear picture of the mix of gases down through the atmosphere from the cloud-tops to the near-surface," she says. For example, DAVINCI+ will make detailed measurements of water vapour in the atmosphere, and so hopefully will reveal how much water the planet has lost over its history, and for how long it might have possessed an extensive ocean. And with any luck, it'll get to the bottom of the phosphine mystery. "I think it's urgent to get back to our sister planet Venus now, and to take the right measurement tools with us so we can decipher what is going on in its atmosphere," Trainer says.

ABOVE The James Clerk Maxwell Telescope in Hawaii, which possibly detected phosphine in Venus's atmosphere

BELOW Venus, as seen by the ALMA telescope

WHAT KIND OF ALIEN LIFE ARE WE LOOKING FOR?

All life on Earth needs three things: DNA and RNA for storing genetic information, proteins for making structural components of a cell and running biochemical reactions, and fatty lipid molecules that make up an outer membrane of a cell. We therefore know that this chemical system works for biology, but when searching for life on other worlds it's important to not be too blinkered by the terrestrial example: alien life could be very different from us.

Based on the fundamentals of chemistry, life in the Solar System is thought most likely to be built from organic (carbon-based) molecules, and use water as the solvent (although perhaps life on Titan uses ethane instead). The instruments we design for probes sent to other worlds therefore look for complex organic molecules in general, rather than specific compounds like DNA.

A lot of the work of space missions is about trying to understand what the environment on other planets and moons is like – or was like billions of years ago – and whether these conditions could be habitable for life. Our understanding of the survival limits of terrestrial life is informed by studies of extremophiles – ultra-hardy organisms that tolerate boiling hot or freezing cold temperatures, or high acidity, or punishing levels of radiation, or the desiccating effects of salty surroundings. Some extremophiles live in environments on Earth that are similar to other worlds. For example, Lake Vostok, buried under the Antarctic ice sheet, helps guide us on the chance of life beneath the surface of Europa or Enceladus.

ABOVE AND BELOW Scientists looking for alien life in our Solar System take inspiration from extreme conditions on Earth, such as salty, hot or icy environments. Here are some artist's impressions of the type of life that could exist on Mars

MARS

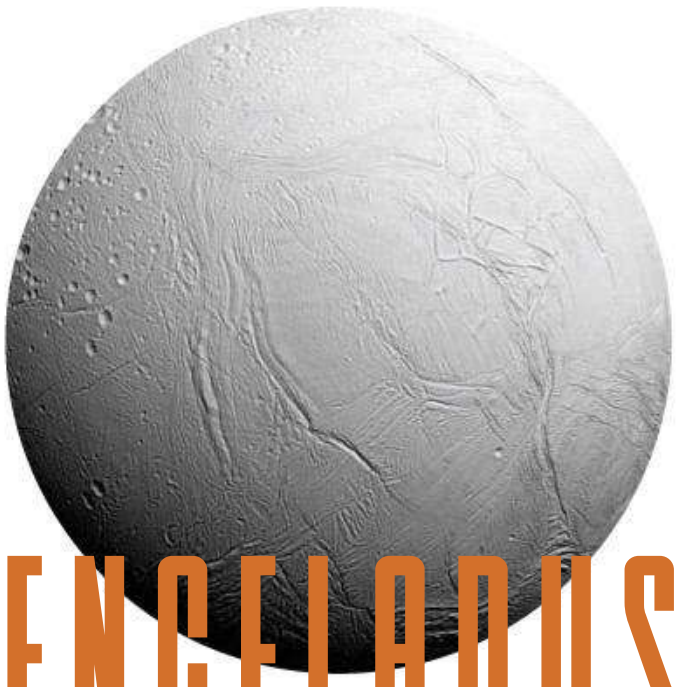
Testing of the Rosalind Franklin rover

LOCATION: 228 MILLION KILOMETRES FROM THE SUN
PROS: EXTENSIVE EVIDENCE OF ANCIENT LIQUID WATER, ORGANIC MOLECULES, ENERGY SOURCES
CONS: EXTREMELY COLD AND DRY SURFACE
MISSIONS PLANNED: TIANWEN-1, AL HAMAL, PERSEVERANCE (EN ROUTE); ROSALIND FRANKLIN (2022 LAUNCH)

While some 19th-Century astronomers may have convinced themselves they could see canals criss-crossing the surface of Mars, our first close-up look at the Red Planet with flyby probes in the 1960s plainly revealed the Martian surface to be a freeze-dried desert. Mars has a thin atmosphere, which means it is exceedingly cold. Liquid water isn't stable over most of its surface, and it is also bathed in ultraviolet radiation from the Sun. But Mars hasn't always been this inhospitable – there are extensive signs of ancient river valleys, deltas, lakes, and possibly even an ocean over its northern hemisphere, which indicate a warmer, wetter primordial Mars. Did life get started during this earliest phase of the planet's history, and might 'biosignatures' of these microbes remain preserved in sedimentary deposits?

Scientists interested in the chances of life on Mars explore extreme environments here on Earth, and investigate what sorts of microorganisms are able to survive. Dr Claire Cousins is an astrobiologist at the University of St Andrews. "While nowhere on Earth can be exactly like Mars, there are places that have enough similarities to make them valuable comparisons," she says. "If you wanted to get a feel for what the bone-dry Martian surface is like today, you could go to the Atacama Desert in Chile. Alternatively, to understand the environment of early Mars – some three to four billion years ago – you could study volcanically active places like Iceland."

Mars is exciting not only because it seems to have once offered a habitable environment for life, but being our planetary neighbour it is relatively easy to get to and explore with robotic probes. In July of this year, no fewer than three separate missions were launched to Mars: China's Tianwen-1 orbiter and rover, the United Arab Emirates' Al Amal orbiter, and NASA's latest car-sized rover, Perseverance. And when the launch window next opens in 2022, the European Space Agency (ESA) and Russia's Roscosmos will be sending their own biosignature-hunting robot, the ExoMars rover Rosalind Franklin. Cousins is also a member of the camera team for ExoMars. "The next rovers heading for Mars will probe the chemistry of Martian rocks in incredible detail. This is important because we're trying to find evidence of tiny microscopic life that lived a few billion years ago – not easy!" she says. "We'll be looking for trace amounts of organic material left behind by any microorganisms that have been preserved that whole time."



ENCELADUS

LOCATION: SATURN SYSTEM; 1,400 MILLION KILOMETRES FROM THE SUN
PROS: SUBSURFACE SEA, ORGANIC CHEMISTRY, ENERGY SOURCES
CONS: SEALED BENEATH ICE SHELL
MISSIONS PLANNED: NONE CURRENTLY SELECTED

Enceladus, one of Saturn's moons, is a tiny snowball of a world. Its diameter would fit comfortably between London and Edinburgh, its minuscule gravity cannot cling onto any meaningful atmosphere and its surface is hard-frozen ice. Astrobiologists didn't give it a second's thought, until a surprise discovery in 2005. The Cassini probe saw that fractures near the moon's south pole were spewing glittering geysers of water ice out into space. Over time, the out-jetting of these ice crystals have built up the E ring around Saturn, and it's believed they are being squirted from a large body of liquid water lying beneath the moon's icy crust.

After this stunning discovery, Cassini was ordered to skim low over the surface of Enceladus and plunge straight through these diffuse water jets to analyse their composition. The fountains were found to contain sodium and grains of silica-rich sand – Enceladus' sea is salty, and this is important because it means the water must be in contact with the rocky core of the moon to dissolve out minerals. Cassini also detected simple organic compounds like formaldehyde and acetylene, as well as some larger molecules. These aren't signs of life, but are just the sort of precursor chemistry that is thought to be important in the development of biology.

Then, in April 2017 – shortly before the mission ended in a dramatic plunge into the crushing atmosphere of Saturn – the Cassini team announced the discovery of possible hydrothermal activity on Enceladus's seafloor. Hydrothermal vents form oases for microbial life in the dark depths of Earth's oceans, and the hydrogen gas detected in the plumes of Enceladus is an available food source for life. On Earth, certain microbes derive the energy they need by combining hydrogen with carbon dioxide, producing methane in the process.

So Enceladus seems to tick all the necessary boxes for providing a habitable environment suitable for life: liquid water, organic compounds and energy sources. Several robotic missions for taking a closer look have been proposed in recent years. Enceladus Life Finder (ELF) and Enceladus Life Signatures and Habitability (ELSAH) missions were both proposed to the most recent round of NASA's New Frontiers Program but lost out to Dragonfly. Explorer of Enceladus and Titan (E^2T) was proposed as a joint ESA-NASA mission, but in May 2018 wasn't shortlisted for the latest round of ESA's Cosmic Vision programme. The competition is fierce for the funding of space missions, but there is enough excitement about Enceladus that we will surely return there soon enough.

Graphic of Cassini plunging through plumes of water jets erupting from Enceladus

ESA, NASA X2

LIFE BEYOND THE SOLAR SYSTEM

There are a handful of planets and moons in the Solar System that may harbour life, but there are an awful lot of other planetary systems out there in our Galaxy.

Since the early 1990s, astronomers have discovered over 4,300 exoplanets (planets beyond our Solar System), and some estimate there could be 100 billion or more in the Milky Way. Although moons like Europa or Enceladus could support a biosphere, it's hard to tell in an ocean that is sealed beneath a shell of ice. Therefore, when considering life beyond the Solar System, astrobiologists mostly consider more Earth-like planets. Large telescopes can remotely read the atmospheric composition of exoplanets, and if we see the presence of gases like oxygen we could infer the presence of life there.

"We'll get our first chance of detecting biosignatures with the James Webb Space Telescope when it launches in October 2021, but we'll only be able to check a handful of habitable planets," says Dr Sarah Rugheimer, an astrobiologist and astrophysicist at the University of Oxford. And which does she reckon the best candidate planets might be? "I think the TRAPPIST system will be an amazing system to explore as we have a series of seven Earth-sized planets at different distances from that star."

EUROPA

DISTANCE FROM EARTH: JUPITER SYSTEM; 778 MILLION KILOMETRES FROM THE SUN
PROS: SUBSURFACE SEA, POSSIBLE ORGANIC CHEMISTRY, POSSIBLE ENERGY SOURCES
CONS: SEALED BENEATH ICE SHELL
MISSIONS PLANNED: JUICE (2022 LAUNCH), EUROPA CLIPPER (2024 LAUNCH)

Space probes have revealed the surface of Europa, one of Jupiter's moons, to be relatively fresh and young. It is scarred by few impact craters, which means the moon is geologically active. Europa is criss-crossed with long fractures from where the moon's surface is being stretched and flexed by the powerful gravity of Jupiter. The Galileo orbiter also noticed the moon distorting Jupiter's magnetic field. This implied that a magnetic field was being created within Europa by an electrically conductive substance – an ocean of salty water beneath Europa's surface being the ideal candidate. There even appear to be regions where this ocean may have melted through to the surface, breaking off icebergs, before rapidly freezing over again with

Europa rising above Jupiter's cloud tops

The planets within the TRAPPIST-1 solar system will be good candidates to hunt for alien life

ESO, NASA/JPL X3

exposure to the cold of outer space. Therefore, in terms of the potential habitability of Europa, we know it harbours a great subsurface ocean of liquid water. But that's just about all we can be sure of. We don't know how thick the ice shell on top of the ocean is, or what organic chemistry may be there, or whether there is any hydrothermal activity on the seafloor, or whether the pH or saltiness of the seawater is suitable for life.

If this ocean is habitable, then Europa offers much better prospects for extraterrestrial life surviving today than Mars (which is now exceedingly cold and dry), but the moon is tricky to explore with robotic probes. Europa is much further away than Mars or Venus, it orbits within the intense radiation belt of Jupiter, and the moon has no atmosphere for parachuting to the surface. And even if we can get a hardy probe safely down onto the face of Europa, it might need to drill or melt down through many kilometres of rock-hard ice to reach the subsurface ocean. In some respects, Enceladus would be much easier to check for life because it is conveniently squirting its seawater out into space for us – a probe could swoop through this water plume to collect a sample before looping back to the Earth for analysis. There is hope for Europa, however, after the Hubble Space Telescope spotted what seems to be water plumes erupting from near the moon's south pole.

ESA's Jupiter Icy Moons Explorer (JUICE) is launching in 2022, but will only make two flybys of Europa, whereas NASA's Europa Clipper will make multiple passes of the moon and should launch in 2024. If the Europa Lander mission receives funding it could launch in 2025 and will be able to scoop 10cm into the surface ice to test for signs of life.

TITAN

DISTANCE FROM EARTH: SATURN SYSTEM; 1,400 MILLION KILOMETRES FROM THE SUN
PROS: GEOLOGICALLY ACTIVE, ORGANIC CHEMISTRY
CONS: VERY COLD, LIQUID HYDROCARBONS
MISSIONS PLANNED: DRAGONFLY (2027 LAUNCH)

Saturn's largest moon, Titan, is enormous, larger even than the planet Mercury. When ESA's Huygens descent probe parachuted down through Titan's hazy orange atmosphere in 2005, it discovered a landscape with rolling hills, networks of river valleys, and smoothed pebbles strewn across the ground. Flybys from the Cassini spacecraft subsequently found great lakes and signs of rain near the moon's north pole. Titan is sodden wet and smothered with the sort of simple organic chemistry thought to have been important for the origin of life on primordial Earth – surely this is a surefire winner for hosting extraterrestrial biology?

The problem with Titan is that it is really cold. It orbits Saturn, nine times further from the Sun than the Earth and so only receives about 1 per cent the amount of solar warming. The surface is a numbing -180°C, and Titan's rivers and lakes don't slosh with liquid water, but liquid hydrocarbons like methane and ethane. This means that any life on the surface would have to be ethane-based rather than water-based, and molecules like DNA won't work. Titan life would be truly alien.

Astrobiologists are keen to return to Titan. In June, NASA selected Dragonfly as the latest mission to be funded by its New Frontiers Program. Dragonfly is a truly innovative endeavour – where other planetary probes have involved a static lander or a rover to trundle slowly across the surface, Dragonfly is an octocopter drone. Titan's combination of low gravity and thick atmosphere makes it suited for exploration by air, and the craft will be able to fly faster than 30km/h, and take off and land vertically, giving it an unprecedented capability to pinpoint sites of interest.

Trainer is also deputy principal investigator on this mission. "While Dragonfly is not a life-detection mission, we are going after really fundamental questions about how far prebiotic chemistry may have progressed in this environment. We will characterise the products of millions of years of chemical synthesis, and search for biologically relevant molecules". SF

by **PROF LEWIS DARTNELL**
Lewis is an astrobiologist and writer, who studies how microbial life might survive on Mars. His latest book is ORIGINS: How The Earth Shaped Human History *(£9.99, Vintage).*

SFP357

BBC **Science Focus** MAGAZINE

SUBSCRIPTION ORDER FORM

Please complete the order form and send to:
FREEPOST IMMEDIATE MEDIA *(please write in capitals)*

UK DIRECT DEBIT

☐ Yes, I would like to subscribe to/renew *BBC Science Focus* paying £34.99 every 14 issues – saving 52% *

YOUR DETAILS (ESSENTIAL)**

Title _____ Forename _____
Surname _____
Address _____
_____
_____ Postcode _____
Home phone no _____
Mobile phone no** _____
Email** _____

☐ **I wish to purchase a gift subscription**

GIFT RECIPIENT'S DETAILS (ESSENTIAL)**

Title _____ Forename _____ Surname _____
Address _____
Postcode _____ Home phone no _____
Mobile phone no** _____
Email** _____

Instructions to your bank or building society to pay by Direct Debit

DIRECT Debit

To: the Manager (bank/building society)

Address

Postcode

Name(s) of account holder(s)

Bank/building society account number

Branch sort code

Reference number (internal use only)

Originator's identification number

7 1 0 6 4 4

Please pay Immediate Media Co Bristol Ltd debits from the account detailed in this instruction subject to the safeguards assured by the Direct Debit Guarantee. I understand that this instruction may remain with Immediate Media Co Bristol Ltd and, if so, details will be passed electronically to my bank/building society.

Signature

Date / /

KEEP IN TOUCH

BBC Science Focus Magazine* (published by Immediate Media Company Limited) would like to send you updates, special offers and promotions by email. You can unsubscribe at any time. **Please tick here if you would like to receive these ☐

We would also like to keep in touch by post and telephone about other relevant offers and promotions from Immediate Media. If you do not wish to be contacted this way please tick here post ☐ phone ☐. For more information about how to change the way we contact you, and how we hold your personal information, please see our privacy policy which can be viewed online at **immediate.co.uk/privacy-policy**

OTHER PAYMENT METHODS

☐ **UK cheque/credit/debit card** – £34.99 for 14 issues, **saving 52%**
☐ **Europe** inc Eire – £73.35 for 14 issues
☐ **Rest of world** – £74.75 for 14 issues
☐ I enclose a cheque made payable to Immediate Media Co Ltd for £ _____

Visa ☐ Mastercard ☐ Maestro ☐

☐☐☐☐ ☐☐☐☐ ☐☐☐☐ ☐☐☐☐ ☐☐☐☐

Issue no ☐☐ Valid from ☐☐☐☐ Expiry date ☐☐☐☐

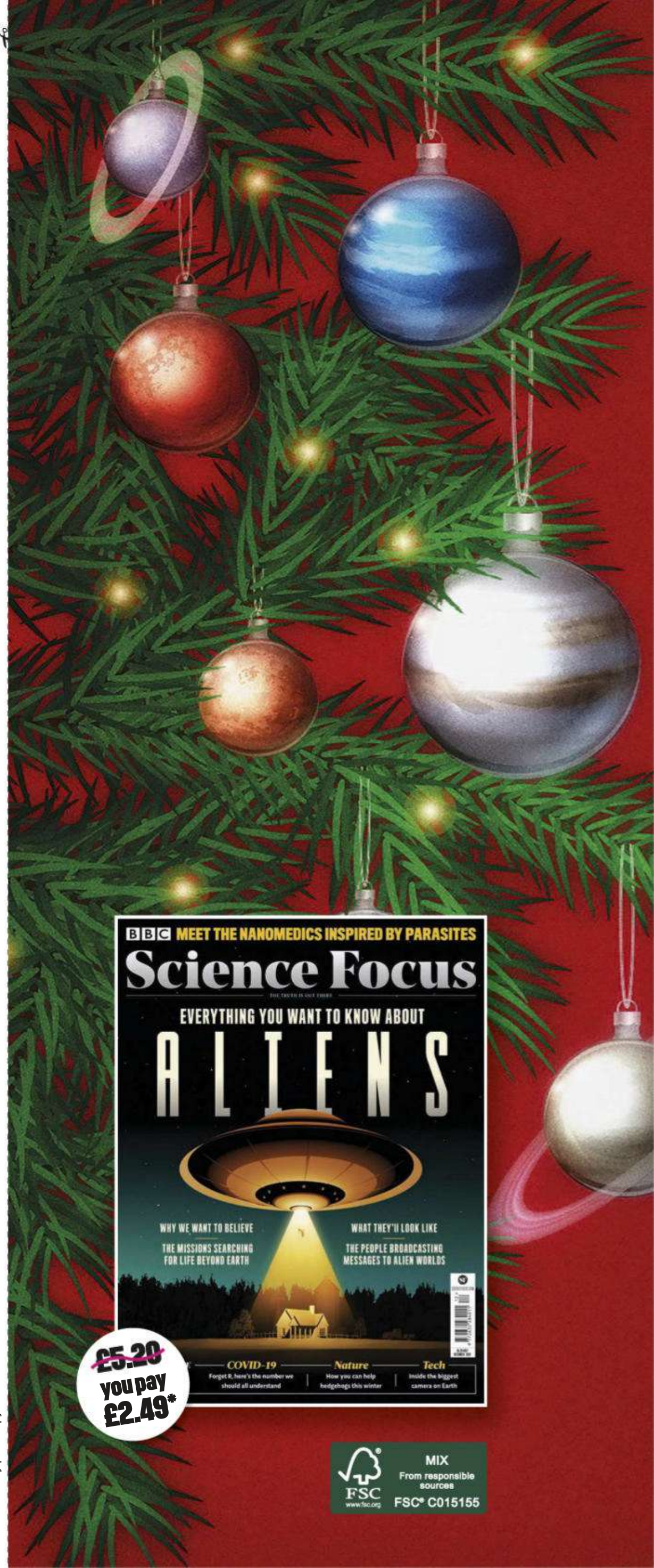
Signature _____ Date _____

If credit card address is different, please use the order hotline 03330 162 113

OVERSEAS Please complete the order form and send to: *BBC Science Focus Magazine*, PO Box 3320, 3 Queensbridge, Northampton, NN4 7BF

***Offer ends 31 December 2020.** 52% saving is only available to UK residents. Personal subscriptions start with the next available issue. Gift subscriptions start with the Jan issue mailed out after Christmas.

You may photocopy this form



INTRODUCTORY CHRISTMAS SUBSCRIPTION OFFER

SAVE 52%

WHEN YOU SUBSCRIBE TO *BBC SCIENCE FOCUS MAGAZINE* TODAY*

- Save 52% on an annual subscription
- Pay just £34.99 every 14 issues by Direct Debit, saving 52%!*
- Receive every issue delivered direct to your door with FREE UK delivery

Online
buysubscriptions.com/SFP357

Phone
03330 162 113†
(please quote SFP357)

Post
FREEPOST IMMEDIATE MEDIA
(please write in capitals)

† UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) and are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). Outside of free call packages call charges from mobile phones will cost between 3p and 55p per minute. Lines are open Mon to Fri 9am-5pm. If calling from overseas, please call +44 1604 973 721

FROM THE MAKERS OF BBC Sky at Night MAGAZINE

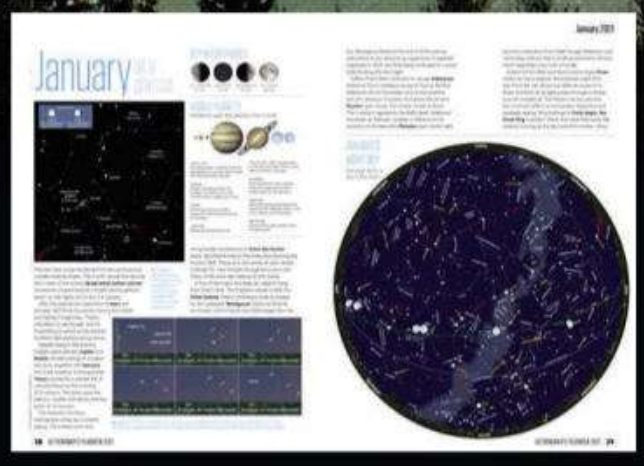
The Astronomer's Yearbook 2021

Get ready to explore the best stargazing sights in the night sky over the next 12 months with *The Astronomer's Yearbook 2021*. This indispensable guide from *BBC Sky at Night Magazine* contains a year of stargazing tips, how-to guides and equipment details. Monthly star charts guide you to the best views in 2021 and will help you keep track of the eclipses, oppositions, occultations and meteor showers coming up. With expert advice on the constellations of each season, challenging objects to track down and more, you'll be ready for all the top astronomical events in 2021.

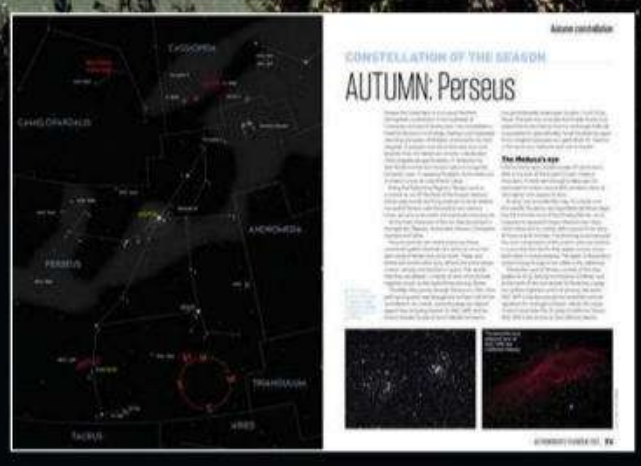
PLUS Receive FREE P&P on this special edition

Chris Bramley,
Editor, *BBC Sky at Night Magazine*

BBC
SCIENCE FOCUS COLLECTION
Sky at Night MAGAZINE
PRESENTS
THE ASTRONOMER'S YEARBOOK 2021
ONLY £9.99 INC P&P*
£9.99
Your guide to the stars throughout the year
Where and when to find the planets
Detailed month-by-month star charts
Tips to make stargazing fun for all the family
Be a lunar pioneer with our guide to the Moon
Expert reviews of the year's top new kit



Our month-by-month guide and detailed star charts reveal what to look for and when, from stars and planets to Moon phases and more.



Get to know the stand-out constellations of each season, as we highlight their brightest targets and how to best observe them.

Develop your skills with our Challenge Yourself projects, whether it's classifying Moon craters or recording sunspot activity.

ORDER YOUR COPY TODAY

visit: www.buysubscriptions.com/Yearbook2021

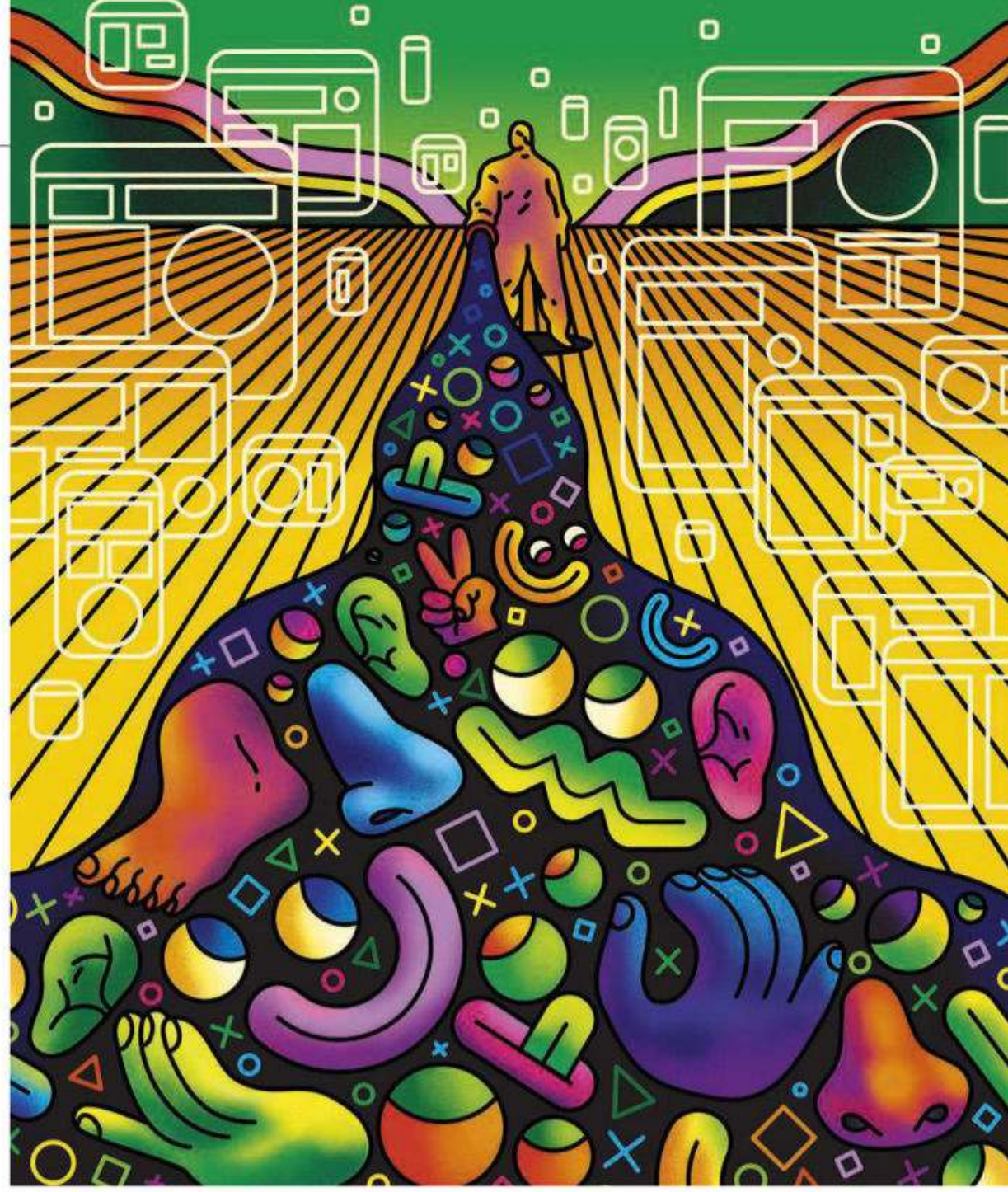
Alternatively call 03330 162138† and quote 'The Astronomer's Yearbook 2021'

† UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) and are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). Outside of free call packages call charges from mobile phones will cost between 3p and 55p per minute. Lines are open Mon to Fri 9am–5pm. *Free delivery on UK orders only. Prices including postage are: £9.99 for all UK residents, £12.99 for Europe and £13.49 for the Rest of World.All orders are subject to availability. Please allow up to 21 days for delivery.

COMMENT

IN SEARCH OF DARKNESS

The nights might be getting longer, but the internet is open and ready for business 24 hours a day. Is this a good thing?



When I think back to it, it was a very strange time. I was lying on a ward bed in a disused hospital on the outskirts of Glasgow. My face was dripping with fake blood and slime. The lights were hot. We'd been there for seven hours. But after many random sleep-deprived moments of weirdness, a rubber head burst through my chest – my cue to gasp out the last few lines of a review of the video game *Aliens Versus Predator*. All of this for the service of a few night owls who'd tuned into Channel 4's late-night experimental strand, 4Later.

The TV show I was working on was called *Bits*, and it was 1999. Our team was trying to make a weekly programme of broadcast quality within an infinitesimal late-night budget. There was a lot of creativity and very few rules, mostly because no one was watching. The show went out way after people's bedtimes on random nights of the week at random times in the schedule. It was perfect nocturne fodder.

There's a certain kind of media that plays to a middle-of-the-night crowd. It's dreamy. It's incongruous. It's usually where new ideas bounce off others and form organisms that eventually become prime time. And that's because the intimate, anything-can-happen night-time feeling is at the other end of the spectrum from the logical and play-tested stuff that's appropriate for daylight hours. The cloak of night gives us permission to skulk around and observe, unobserved. As writer Helena Fitzgerald described it in a recent episode of *Digital Human*, it's the emotional quality of being the last two people awake at a slumber party. And a long time ago, around the same time as I was covered in goo, the place she went to feel it at any time of the day or night was the internet.

"We need to know that everyone else is asleep to feel like we are sharing a different reality"

For a generation who grew up with the virtual space as somewhere new, the experience of 'night' became detached from the clock. It was always the middle of the night somewhere, and this suffused the things people made and shared on websites and instant messengers. It was an inconsequential space of extreme creativity – of art, of ideas and of the self.

Fast-forward to now and the internet has banished the night. We are bombarded by 24-hour news and compelled to pay attention to ever-refreshing social media updates. Our online selves are extensions of our offline selves – conceptually and practically. Companies track our data and judge us by it. It's always the middle of the day somewhere, and you really don't want to descend into the nightmares where it isn't.

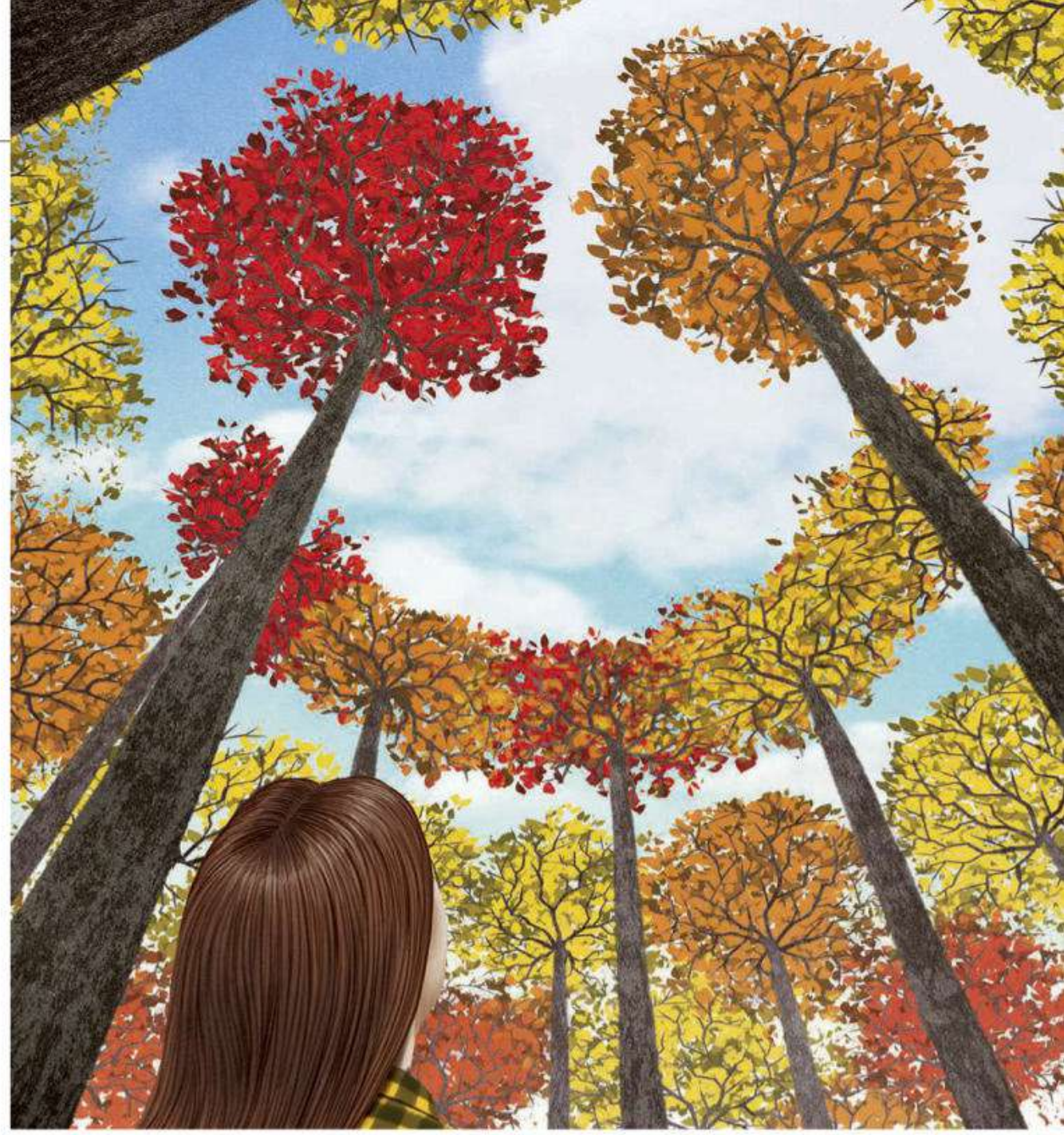
We need night-time encounters to whisper our secrets and share our feelings and express our fantasies. We need to know that almost everyone else is asleep to feel like we are sharing a different reality with the other people who are also awake. The internet used to be where that tribe gathered. Now, we have to go offline to find it, and slip under the covers with our torches and our ghost stories to hush the din of the daytime that is everywhere around us. **SF**

PORTRAIT: KATE COPELAND ILLUSTRATION: SCOTT BALMER

ALEKS KROTOSKI

Aleks is a social psychologist, broadcaster and journalist. She presents *The Digital Human*.

BBC RADIO 4 92–95FM & 198LW



COMMENT

IN PRAISE OF 'AWE' WALKS

Spending time outdoors is great for your health, but there's an easy way to reap even better benefits

There is a wood near me that I walk or run through most days. Even on a wet winter's day I get pleasure from being among the trees, though to be honest, when I am running, I wear headphones to distract myself from the pain in my lungs. But perhaps I should be spending more time appreciating my surroundings by cultivating a sense of 'awe'. Doing that might increase my sense of joy and even my 'smile intensity'. Or at least that was the findings of a study I recently came across, published in the journal *Emotion*.

I have always assumed that spending time in nature is good for me, but a couple of years ago I decided to see if there were any measurable benefits. The BBC series, *Trust Me, I'm A Doctor*, which I present, teamed up with researchers from Edinburgh University. We recruited some volunteers and then randomly assigned them to either a control group, or a group who were asked to spend a couple of hours a week in nature.

The second group were encouraged to spend their lunch hour in parks, but were asked to sit, relax, or gently walk around, not to walk briskly or do any vigorous exercise, as we were trying to see what benefits there might be from being outdoors, rather than the benefits of exercise. At the start and end, our volunteers filled out a questionnaire that assessed things like positive emotion, arousal and stress.

"Those doing the 'awe' walks had smiles that grew more intense as the study proceeded"

We also measured their stress by recording their levels of cortisol, the 'fight-or-flight' hormone. After just three weeks we saw improvements in their cortisol levels, as well as a 30 per cent drop in perceived stress. Surprisingly, the weather didn't seem to make much difference to the stress-busting benefits, with one volunteer saying he sat outside during a hailstorm.

So we showed that just being outside, preferably somewhere green, seems to be good for your mental health. But does cultivating a sense of 'awe' add to it?

To find out, scientists from the Memory and Aging Center at the University of California, San Francisco, divided 60 volunteers into two groups. One group were asked to go for a 15-minute walk once a week for eight weeks, and to spend their time thinking about holidays, work, children, anything 'internal'. The other group were also asked to walk, but to notice the colour of the leaves, the pattern of light on the ground, anything that might induce a feeling of 'awe'. They filled in questionnaires before and after, and it was found that those who were paying more attention to their surroundings got more benefit from their walks. A rather charming element of the experiment is that the researchers asked the volunteers to take selfies at the end of each walk, and they found those doing the 'awe' walks had smiles that grew more intense as the study proceeded. Time to hug a few more trees. SF

MICHAEL MOSLEY

Michael is a writer and broadcaster, who presents *Trust Me, I'm A Doctor*. His latest book is *Fast Asleep* (£9.99, Short Books).

BBC TWO

PORTRAIT: KATE COPELAND ILLUSTRATION: JASON RAISH

GIFT SUBSCRIPTIONS FROM ONLY £29.99

FOOD

12 ISSUES FOR £29.99
SAVE 49%

13 ISSUES FOR £29.99
SAVE 51%

10 ISSUES FOR £19.99
SAVE 43%

HOMES AND GARDENING

12 ISSUES FOR £39.99
SAVE 39%

13 ISSUES FOR £29.99
SAVE 54%

13 ISSUES FOR £29.99
SAVE 54%

13 ISSUES FOR £19.99
SAVE 38%

LIFESTYLE

13 ISSUES FOR £29.99
SAVE 53%

26 ISSUES FOR £59.99
SAVE 39%

13 ISSUES FOR £39.99
SAVE 49%

SCIENCE AND NATURE

14 ISSUES FOR £34.99
SAVE 52%

12 ISSUES FOR £34.99
SAVE 47%

13 ISSUES FOR £29.99
SAVE 51%

13 ISSUES FOR £29.99
SAVE 49%

HISTORY

13 ISSUES FOR £34.99
SAVE 51%

13 ISSUES FOR £29.99
SAVE 58%

SPORT

13 ISSUES FOR £37.99
SAVE 51%

20 ISSUES FOR £39.99
SAVE 29%

13 ISSUES FOR £37.99
SAVE 47%

CRAFT

13 ISSUES FOR £46.99
SAVE 49%

13 ISSUES FOR £44.99
SAVE 46%

TAKE THE HASSLE OUT OF YOUR CHRISTMAS SHOPPING AND GIVE A GIFT THAT LASTS ALL YEAR

ORDER NOW!

Subscribing online is quick and easy. Visit

buysubscriptions.com/christmas

- mobile-friendly site
- safe and secure
- easy search

or call our hotline **0330 053 8660**† **QUOTE CODE: X20AD**

Remember ordering online is safe and secure, choose from any of these payment options

VISA · MasterCard · DIRECT DEBIT · PayPal

SEE OUR FULL RANGE OF MAGAZINES ONLINE

This offer closes on the 31st December 2020 and is valid for UK delivery addresses only. The discounts shown are savings calculated as a percentage of the full shop price, excluding Radio Times and Match of the Day which are calculated as a percentage of the Basic Annual Rate. For overseas rates visit www.buysubscriptions.com. All Christmas gift subscriptions will start with the first issue available in January 2021. Should the magazine change in frequency, we will honour the number of issues and not the term of the subscription. †UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) and are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). Outside of free call packages call charges from mobile phones will cost between 3p and 55p per minute. Lines are open Mon to Fri 9am – 5pm. *Radio Times is published weekly and Radio Times subscriptions are for 26 issues. The Basic Annual UK Subscription Rate of Radio Times is £193. This price is for one year and includes the Christmas double issue and a contribution towards postage.
Match of the Day is published bi-weekly and Match of the Day subscriptions are for 20 issues. The Basic Annual UK Rate for Match of the Day is £67.50 for 25 issues.

SHOULD WE BE SIGNALLING OUR EXISTENCE TO ALIEN LIFE?

Astrobiologist and extraterrestrial researcher **Dr Douglas Vakoch** speaks to **Sara Rigby** about transmitting messages into the cosmos in the hope of finding intelligent extraterrestrial life

PEOPLE MIGHT BE FAMILIAR WITH SETI – THE SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE. YOU'RE THE PRESIDENT OF METI (MESSAGING EXTRATERRESTRIAL INTELLIGENCE). TELL US ABOUT WHAT YOU DO.

METI reverses the process of SETI. SETI, searching for extraterrestrial intelligence, listens for radio or laser signals from space. At METI, we flip it around and instead of listening, we transmit powerful, intentional messages to nearby stars in the hope of eliciting a response.

WHY DO YOU WANT TO SEND OUT A SIGNAL? AND HOW WOULD THAT HELP US FIND ALIEN LIFE?

My big concern is that there are, in fact, a lot of other civilisations out there, but they're doing exactly what we are. They have these robust SETI programmes and everyone is listening, but no one is saying hello. And so this is our effort to join the galactic conversation.

HAVE MESSAGES OF THIS SORT BEEN SENT BEFORE?

Yeah, there have been sporadic messages sent out. The most famous message was transmitted from what was the world's largest radio telescope at the time in Arecibo, Puerto Rico. To demonstrate to extraterrestrials, and ourselves, that we could do it, a brief three-minute message was sent out into the Universe.

The message itself was the numbers from 1 to 10 in the binary format, then a description of chemical elements important to life on Earth in terms of their atomic numbers. And there was a description of our DNA, what we look like, how tall we are, how many of us there are on Earth, what our Solar System is like, what the telescope is like. So it was pretty ambitious to cram a lot of information in three minutes.

At METI, we take a different approach. Instead of trying to send everything, we send something that will be succinct and intelligible. My concern of sending everything is that maybe nothing will be understandable. So we take the opposite strategy and – instead of an encyclopedia – we send a primer that is really targeted to alien scientists.

IS THE ARECIBO SIGNAL LIKELY TO BE HEARD? THREE MINUTES IS QUITE A SHORT BURST OF INFORMATION.

It's quite a short burst. And it doesn't follow the protocols that SETI scientists use here on Earth. A one-off transmission is not enough. The other huge problem of the Arecibo message is if it's detected by the target recipients and they send a reply, we're not going to get that reply for ➲

DR DOUGLAS VAKOCH

Dr Douglas Vakoch is the president of Messaging Extraterrestrial Intelligence (METI), based in California. He is an astrobiologist, extraterrestrial researcher, and psychologist, and an elected member of the International Institute for Space Law. Before founding METI, he worked at SETI for 16 years. He has also edited numerous books about psychology, space exploration and extraterrestrial intelligence.

IAN CURCIO/TEDX GREENVILLE

50,000 years. The message was sent as an afterthought. As the Arecibo telescope is built into the surface of the Earth, you can only point about 10° of either side of straight up, so the question was: what's pretty much overhead? And there's a prominent globular cluster of stars called M13 that was in target at the appropriate time. But it's 25,000 light-years away. So certainly we can do better than that.

In 2017, when we sent our first message as an organisation, we sent it to to Luyten's Star, 12 light-years away. From the transmitter we use in northern Norway, it was the closest star that we could target that was known to have an exoplanet orbiting within its habitable zone. We sent our message three times over and over.

IS THE GOAL TO SEND A SPECIFIC MESSAGE? OR IS IT JUST TO BROADCAST THAT WE ARE HERE?

We want to get a lot of different messages across. One of the things that you'll see in the Arecibo message are a lot of pictures. There's a picture of a human being. A diagram of the Solar System. A diagram of the double helix of the DNA molecule. Well, what happens if the alien is blind? When we sent our message to Luyten's Star, we designed it specifically for a blind alien. So we wanted to push the boundaries a little bit. One of the arguments for vision is that it evolved 40 times independently here on Earth. So we know it's useful, if you have an atmosphere that lets sunlight through. But if you don't, if you've got a murky atmosphere, it's not very useful. Maybe that's what the alien planet is like.

So we designed our radio signal to convey the most essential information that a physicist on another world would need to know to understand the only thing that we have that we can give them directly. And that's the radio signal itself. So we illustrate time by sending pulses of different durations. We illustrate notions of frequency by sending messages of different frequency. Now, does that mean radio waves should be the be-all and end-all of all future messages? Absolutely not. We're developing a variety of messages, and building on this use of radio waves to communicate.

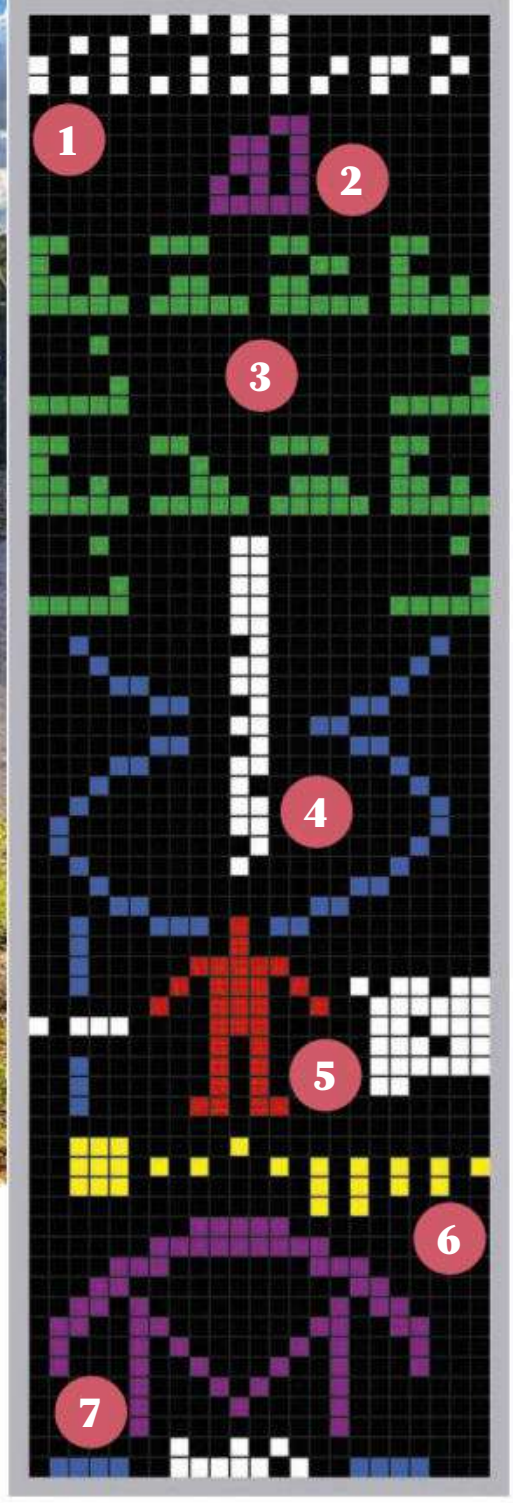
SOME PEOPLE SAY IT COULD BE RISKY TO SEND A MESSAGE TO ALIENS THAT WE KNOW ABSOLUTELY NOTHING ABOUT. DO YOU THINK IT'S RISKY?

I think the point that people miss when they think it's risky is that the aliens we're worried about already know we're here. So if we project our own level of radio technology forwards just 200 or 300 years, we'll have the ability to detect the BBC as it's streaming out at the speed of light, out to a distance of about 500 light-years. Now, we don't currently have the ability to detect the twin of Earth giving off our level of natural radiation or leakage radiation, TV and radio. But that's okay. We also don't have warp drive. We don't have a way of getting to another star. So we're not a threat. But just a tiny bit more advanced than we are, and they already know we're here.

There are a lot of things we have to worry about in this world. Nuclear war, global

"THE PURPOSE OF METI IS TO REACH OUT TO ANOTHER CIVILISATION AND SAY NOT ONLY ARE WE HERE, BUT WE WANT TO MAKE CONTACT"

ABOVE The Arecibo radio telescope in Puerto Rico, which sent out a message containing information about humanity in 1974



LEFT When the 1974 Arecibo message is translated, it resembles the image seen here. It shows:
1 The numbers from 1 to 10 in binary
2 The atomic numbers of hydrogen, carbon, nitrogen, oxygen and phosphorus, which make up DNA
3 The nucleotides of DNA
4 The double helix structure of DNA
5 Human form, human height and human population
6 The Solar System
7 The Arecibo telescope

ABOVE The Fermi paradox is named after Italian-American physicist Enrico Fermi (pictured), who asked why there was a lack of evidence of alien life, if there is a high probability that it exists

warming. It would be nice to take one existential threat off the list of worry. So I wish I could tell you that we would be safer if we didn't send out intentional messages in good conscience. I can't, though. Because if there's anyone out there, then they know we're here. And, even before the radio signals, they've had two billion years to know that there's complex life on our planet by the changes in our atmosphere.

I THINK THE BIGGER QUESTION IS, IF THEY ALREADY KNOW WE'RE HERE, THEN WHAT'S THE POINT?

So the purpose of METI is not to let the aliens know we're here for the first time. It's probably not going to be news to them. Instead, it is examining a question that the Italian physicist Enrico Fermi asked back in 1950. If they're out there, where are they? It's been called the Fermi paradox.

One answer to the Fermi paradox that really motivates what we do at METI is called the 'zoo hypothesis'. So imagine you and I go to London Zoo and we're checking out a bunch of zebras. We're looking at them. We're just getting ready to move on. But all of a sudden, one of them turns directly towards us, looks us in the eye, starts pounding out a series of prime numbers with its hoof. I don't know about you, maybe you're going to go and check out the wildebeest, but I'm going to stay with the zebra and I am going to engage it. And so it would establish a radically different relationship. We knew the zebras were there before. They just weren't especially interesting, or at least there was no indication that they were trying to reach out to us.

That's what we're trying to do with METI, is to reach out to another civilisation and say not only are we here, which you already know, but we want to make contact.

DO YOU THINK IT IS LIKELY THAT SENDING A MESSAGE OUT WILL GET US A MESSAGE BACK?

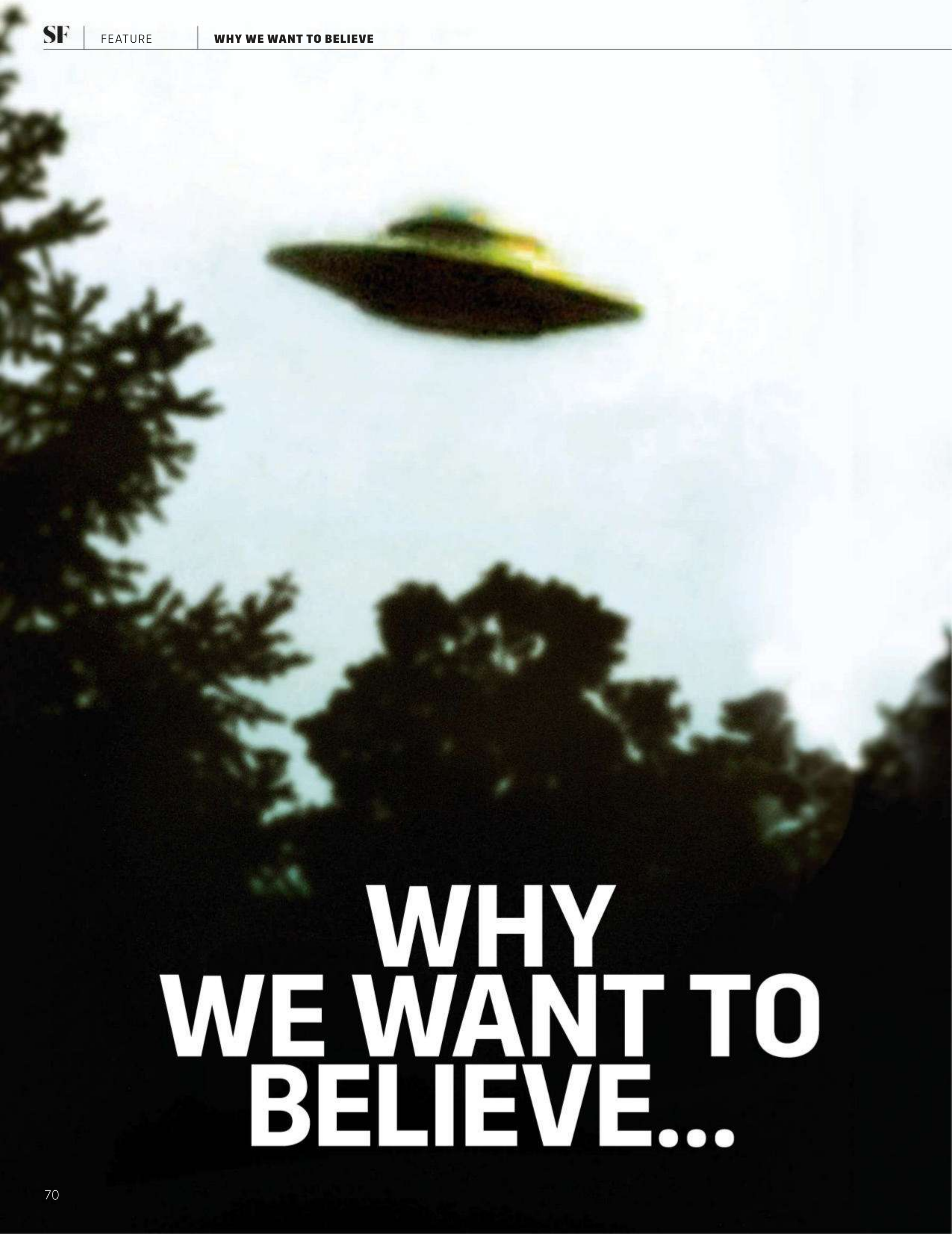
I think there's a really good chance that it will work if we're patient. And I think that's the critical thing.

Am I holding my breath that in 2042 we're going to get a reply back from Luyten's Star that we pinged in 2017? No. I mean, I'm going to be listening. I don't think there's a good chance. But if we repeat that experiment a hundred times or a thousand times or a million times, then I think we have a realistic chance. SF

DISCOVER MORE

ON THE PODCAST *Listen to our full interview with Douglas Vakoch on the* Science Focus Podcast.

GETTY IMAGES X2



WHY WE WANT TO BELIEVE...

Whether they're tiny microbes or little green men, aliens never fail to capture our imagination. So why do they have such a hold on our collective psyche?

by Sue Nelson

Out of nowhere, an incandescent light dazzles a young woman. After her eyes adjust to the brightness, they widen in fear as a small grey figure emerges…

Several weeks later, the woman is pregnant. There has been no physical conception but the pregnancy dates back to that strange event. At night, shards of memory interrupt her dreams. They are of a strange being not from this Earth.

It's not just sci-fi fans who will recognise this scenario. One of history's most famous stories also features an otherworldly being mysteriously impregnating a young woman. In the Bible, over 2,000 years ago, the angelic visitation resulted in the birth of Christianity. Today, there are plenty of people who view the existence of extraterrestrials not just as a matter of belief, but also akin to a religion. There's even a scientific link between the two.

ALIENS VS RELIGION

Andrew Abeyta, assistant professor of psychology at North Dakota State University in the United States, studies the meaning of life. In 2017, he was co-author of a study called 'We are not alone', which found that people who believe in aliens are less likely to believe in religion.

"Religion is a really robust source of meaning in life. It gives us a sense of purpose. We feel important. It feels like our lives are planned, that they're purposefully designed," says Abeyta. "And when we reject religion, what we argue is that need to explain, that need to find purpose, that desire to feel important and meaningfulness doesn't go away. People who tend to report a stronger belief in UFO conspiracies and little green men and things like that, tend to also report a higher sense of meaning in life. They want to go somewhere else to help restore that meaning. So it's sort of like we're trying to capture this compensatory process."

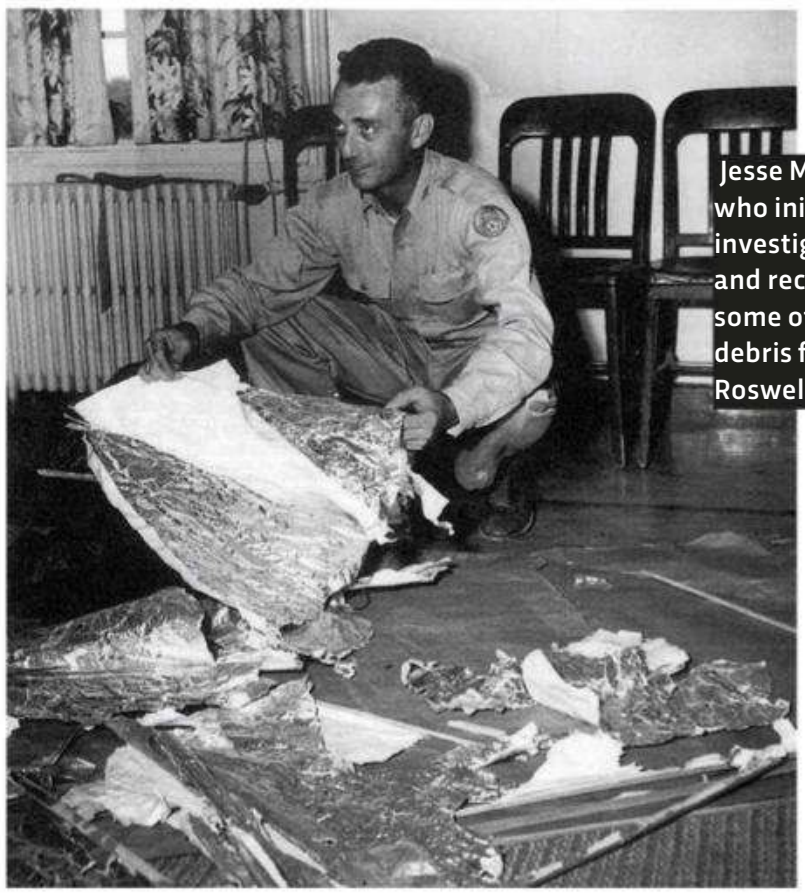
This doesn't necessarily mean that anyone who leaves the church will start believing in alien abduction. But it does demonstrate a common human desire for answers to an age-old question: "Why are we here?"

Research by the University of Fribourg found that those who believe in a higher purpose, the literal truth of the Bible and divine creation, were also more likely to believe in conspiracy theories.

"Belief in conspiracy theories does tend to correlate with religious belief," says Karen Douglas, professor of social psychology at the University of Kent. "It also correlates negatively with education. For instance, people who are more educated are more likely to reject conspiracy theories. Some studies have also shown that disadvantaged groups are sometimes more likely to believe in conspiracy theories."

TAKE ME AWAY

The desire for escapism through conspiracy theories is understandable. And in some countries, conspiracy theories are extremely prevalent. Earlier this year, an Ipsos poll in the US found that almost one in two Americans think that UFOs exist and have already visited the Earth. The study came out before the pandemic took hold. Since then, many ➤



Jesse Marshall, who initially investigated and recovered some of the debris from Roswell in 1947

GETTY IMAGES X2

UNEXPLAINED UFO SIGHTINGS

MANY OBJECTS HAVE BEEN MISTAKEN FOR UFOS, FROM NATURAL PHENOMENON SUCH AS LIGHTNING SPRITES AND METEORS, TO EXPERIMENTAL AIRCRAFT AND WEATHER BALLOONS. THE FRENCH UFO RESEARCH GROUP, GEIPAN, FOUND THAT 3.5 PER CENT OF SIGHTINGS REMAINED UNIDENTIFIED. HERE ARE A FEW THAT, SO FAR, HAVE DEFIED EXPLANATION

people are more anxious and uncertain about the future. If the survey was repeated today, would figures go up?

"Conspiracy theories do tend to thrive in times of crisis," says Douglas. "When people feel isolated and frustrated, they might be more inclined to turn to conspiracy theories in an attempt to make themselves feel better."

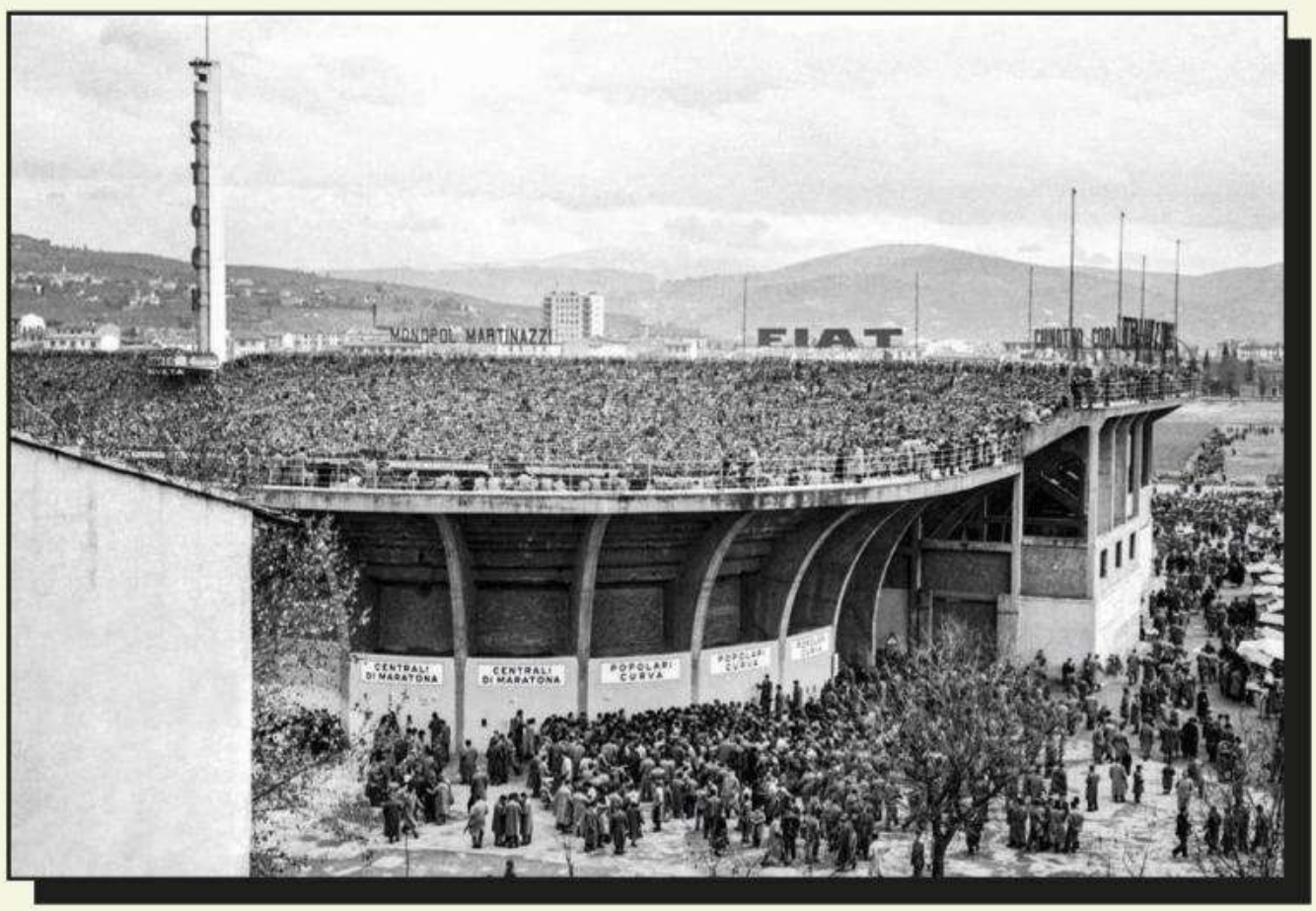
MAKING MEMORIES

The problem with conspiracy theories – whether aliens, 5G masts or vaccines – is that people can also write off a logical explanation as part of the conspiracy.

"People are most susceptible when important psychological needs are not being satisfied," says Douglas. "Specifically, people need knowledge and certainty, to feel safe, secure and in control, and to feel good about themselves and the groups they belong to. When people are not fulfilled by official or conventional explanations for events, conspiracy theories might seem appealing."

The most famous UFO conspiracy theory demonstrates this. In 1947, not long after WWII, which had removed certainty in most people's lives, the Roswell Army Air Field (RAAF) recovered debris from a crashed high altitude weather balloon in Roswell, New Mexico. At least, that was the official story. The *Roswell Daily Record* front page reported it somewhat differently: "RAAF captures flying saucer on ranch in Roswell region".

The conspiracy that launched a global industry of books, TV series and movies involved a spacecraft and recovered alien bodies. It continues to this day. In 1994, even though the craft was confirmed as a weather balloon as part of the military's secret Project Mogul, people continue to believe the balloon was a UFO and that its wreckage, and



UFOS STOP PLAY

In 1954, two local football clubs were playing in Florence, Italy, when the crowd stopped watching the game. Instead, around 10,000 fans were looking upwards at a strange craft. It was described by witnesses as either cigar- or egg-shaped along with silvery white threads falling from the sky. Samples mostly disintegrated on contact, but some were examined at the University of Florence and found to contain boron, silicon, calcium and magnesium. While migrating spiders, which use webs as sails, were suggested as a rational answer to this aspect of the sighting, their silk is an organic compound and does not contain any of those elements.

the preserved body of an alien, is hidden somewhere in the Nevada military base, Area 51.

Psychologist Chris French is not surprised. "The important thing is prior belief and then what we call top-down processing," says the emeritus professor at Goldsmiths, University of London, and former editor of *The Skeptic* magazine. "It's the way that your beliefs and expectations can shape what you actually perceive."

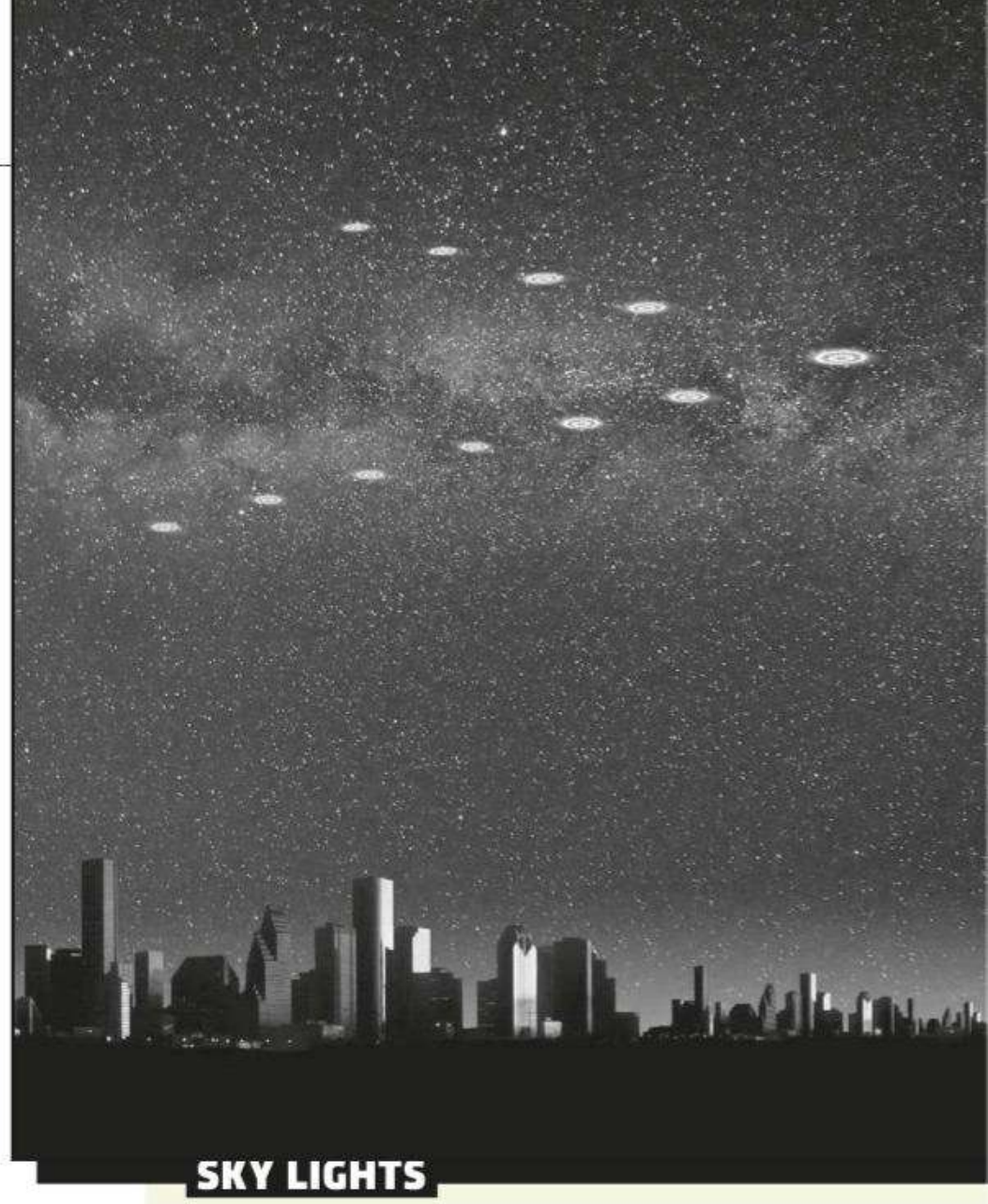
A case in point is the common description of UFOs as 'flying saucers'. The phrase originated just a few weeks before the Roswell incident when businessman and amateur pilot Kenneth Arnold reported, after a private flight, nine unusual craft moving at speeds far greater than any available technology.

"One of the really interesting things is that when he talked about a saucer, he wasn't talking about the shape of the craft at all," says French. "He described the motion as being like a saucer skipping across water. But this phrase 'flying saucer' was loved by the media. He even drew what he saw at the time – it looks more like a boomerang than a saucer. But what did people then start to report seeing after that? Saucer-shaped craft. It's a lovely example of the influence of top-down processing."

If somebody believes in UFOs, that person is then more likely to believe a light in the sky is a flying saucer and either see or recall features of a physical craft than a non-believer. Reliability of memory too is at play.

"Someone maybe is trying to be as honest and sincere as they can possibly be, but they may well end up adding in details of things that perhaps were not, in fact, really there," says French. "So it's those basic kind of psychological biases that can often come into play here." ➲

ARCHIVIO FOTO LOCCHI FLORENCE, ALAMY, LEE WHITMORE



SKY LIGHTS

In 1997, thousands of people reported lights across several hundred miles of night sky in Arizona and Nevada in the United States, and Sonora in Mexico. These lights were either stationary, or on a moving V-shaped craft in a triangular formation (artist's impression above). The United States Air Force stated that the lights over Phoenix were military flares but the V-shaped UFO remains a mystery.

SAUCERS AT SCHOOL

Around 350 children and teachers at Westall High School in Melbourne, Australia, watched five planes surround a silvery flying-saucer-shaped UFO in 1966. The planes attempted to aerially herd the craft for about 20 minutes before it disappeared. A UFO-themed play park commemorates the event and, to this day, witnesses meet once a year to discuss their experience.

THE BRITISH ROSWELL

In December 1980, US airmen stationed at RAF Woodbridge in Suffolk, England were investigating reports of lights in Rendlesham Forest when they saw red and blue lights and a UFO land. It was described as around three metres high and three metres in diameter and appeared to be standing on fixed legs. The material of the craft was like 'smooth, opaque black glass.'

The next day, indentations were seen on the ground and radiation levels recorded. On a separate night, another member of the US Air Force set out to disprove his colleagues with a tape recorder. He reported lights in the sky that looked 'like an eye winking at you' and observed 'a beam coming down to the ground'. Three years later, the US government released a report that described the encounter, which has become known as Britain's Roswell.

While there remain believers, psychologist Prof Chris French – who has also visited the site – is among many of those who are unconvinced. A local forester said the indentations were caused by rabbits, and the levels of radioactivity were not especially high. As for the lights? "I've heard the tape," says French, "and the lights are in complete synchrony with Orfordness Lighthouse nearby."

False memory experiments reveal how easily people can be mistaken. One commonly used test features a list of associated words. French provides a simple example: snooze, snore, dream, nap, bed, blankets. "All these words are closely related to sleep," he says. "When we test memory afterwards quite a lot people will report the word 'sleep' – even though it wasn't presented."

MEMORIES AND NIGHTMARES

Research into memory and alien abduction at Harvard University also sheds light on human susceptibility. A 2002 study led by Prof Susan Clancy compared three groups: one with conscious memories of an abduction; a second who believed they'd been abducted but couldn't remember it; and a third group with no such claims. The experiment found that the first group of people were more susceptible to false memories. The people who didn't believe they'd been abducted were the least susceptible.

It is a reminder of the power of the mind and the psychological human desire to believe in something. "What you've got there are people who are interpreting various things in their lives,

"WHAT YOU'VE GOT ARE PEOPLE WHO ARE INTERPRETING VARIOUS THINGS IN THEIR LIVES, THAT THEY CAN'T EXPLAIN, AS BEING DOWN TO ALIEN ABDUCTION"

that they can't explain, as being down to alien abduction," says French.

There are other theories for belief in aliens. There is ongoing research into whether some of those with alien abduction claims may have experienced childhood abuse. Some studies have found an association with sleep paralysis, where people experience a temporary loss of muscle control either before falling asleep or after waking up and are unable to move or speak. The experience can be extremely frightening and may also be accompanied by hallucinations or feelings of suffocation. This is believed to be the explanation for a belief in the incubus demon, which would supposedly squat on someone's chest as they lay paralysed in fear, often sexually assaulting women. This might explain the tendency of alien abduction memories to include invasive bodily probing.

All the possible explanations reveal further insight into the human psyche. So when we have a deep-rooted need for certainty and meaning, could a pandemic fuel a rise in alien beliefs?

"Conspiracy theories tend to thrive in times of crisis," says Douglas, "so it definitely makes sense that conspiracy theories are so visible right now. When people feel isolated and frustrated, they might be more inclined to turn to conspiracy theories in an attempt to make themselves feel better."

Persuading people who believe in a conspiracy theory that the truth is not part of the conspiracy is, of course, another matter. "When we presented scientific information about the safety and efficacy of vaccines before presenting conspiracy theories to participants, the conspiracy theories had less impact on their attitudes about vaccinations and intentions to vaccinate," says Douglas. Presenting the information afterwards didn't help because the conspiracy theory "had a chance to stick".

Considering the global phenomenon of alien contact culture, it may therefore be too late to persuade people that UFOs and aliens are not visiting us on a regular basis – from theories that the Peruvian Nazca lines were built to attract aliens, to the Star of Bethlehem being a UFO (even though the most likely explanation is that the star was a comet).

To add another layer of complexity, the lack of confirmed evidence for aliens doesn't mean aliens don't exist. So far over 4,000 known planets have been discovered outside our Solar System. Statistically, considering the size of our Universe, it is far more likely that there is alien life elsewhere.

In June 2020, two physicists even came up with an Alien Civilisation Calculator. It is an update of the famous 1961 Drake Equation for calculating the number of extraterrestrial intelligences in the Galaxy. The new calculator came up with a very specific amount. The answer was 36. Just six short of a number that would have delighted fans of *The Hitchhiker's Guide To The Galaxy*, because then we would have returned full circle to humanity's psychological desire to understand the meaning of life. And this time, we'd have an answer. **SF**

by **SUE NELSON**
Sue is an award-winning science journalist and author of Wally Funk's Race For Space *(£14.99, The Westbourne Press).*

The Nazca lines in Peru were created between 500 BC and 500 AD, and some people believe they were designed to attract aliens

ALAMY, GETTY IMAGES

BBC *Science Focus Magazine* **Reader Survey**

Let us know what you think for a chance to **win a £250 Amazon Voucher!**

Would you like to have your say in the development of *BBC Science Focus Magazine?*

Every year, we carry out research on behalf of BBC Studios that invites readers to share their views about this magazine and other BBC Studios titles.

This essential research is used by BBC Studios and the editors to shape future content and strategy for the magazines. We would really appreciate your time to help us with this research.

To take part in the research and be entered into a prize draw to win a £250 Amazon Voucher, please visit:

bbcstudios.com/survey

The survey will take less than 10 minutes and is being conducted according to Market Research Society guidelines. All of your responses are completely confidential.

Terms and conditions: The prize is one £250 Amazon Voucher. One winner will be drawn at random after the closing date at 23.59 on 31st December 2020. Open to all residents of the UK and the Channel Islands aged 18 years or over except employees of BBC Studios or the BBC, their contractors, members of their families and anyone connected with this prize draw. Only one entry permitted per person. There is no cash alternative and the prize is not transferable. No purchase necessary. The prize draw is subject to the laws of England and Wales. Promoter: BBC Studios Distribution Ltd., 1 Television Centre, 101 Wood Lane, London W12 7FA. Your data will be used for the purposes of administration of this prize draw and in accordance with BBC Studios's Privacy Policy (bbcstudios.com/privacy). Where consent has been provided, BBC Studios may send email marketing messages from which you may unsubscribe at any time.

BBC Science Focus MAGAZINE

Q&A

YOUR QUESTIONS ANSWERED

... WHY DOES A RECORDING INCREASE IN PITCH WHEN SPED UP?
... HOW DOES BUBBLE WRAP BECOME BUBBLY?
... WHAT CAUSES WET DOG SMELL?
... WHY DON'T SPIDERS BLEED TO DEATH IF THEY LOSE A LEG?
... WHAT IS RADIATION BREEDING?
... WHAT WERE THE 'OAKVILLE BLOBS'?
... WHAT IS A WHITE HOLE?
... WHAT WAS THE BIG BANG?
... WHY DOES RUNNING WATER MAKE ME NEED THE TOILET?

Email your questions to
questions@sciencefocus.com
or submit on Twitter at
@sciencefocus

OUR EXPERTS

DR EMMA DAVIES Chemistry expert and science writer

ALEXANDRA FRANKLIN-CHEUNG Environment and climate expert

ABIGAIL BEALL Science and space writer

MARCUS CHOWN Cosmology expert and science writer

DR ALASTAIR GUNN Astronomer and astrophysicist

PROF ALICE GREGORY Psychologist, sleep expert

BEN HOLDER Science writer, TV producer

DR CHRISTIAN JARRETT Neuroscience and psychology expert

DR NISH MANEK Medical expert and GP trainee

DR HELEN PILCHER Biologist and science writer

PROF ROBERT MATTHEWS Physicist, science writer

LUIS VILLAZON Science and technology writer

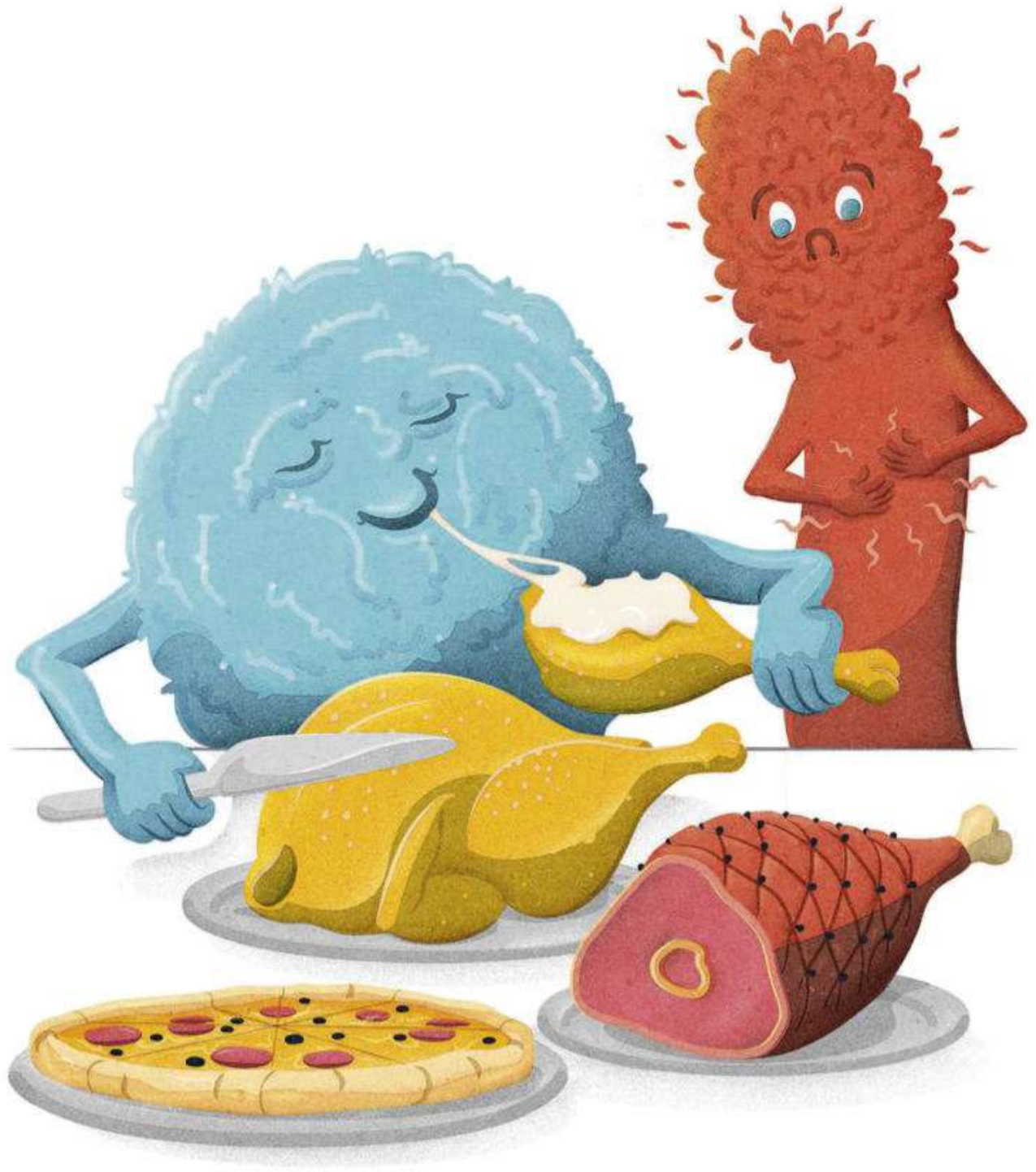


ILLUSTRATION: DANIEL BRIGHT

EVERETT HUGH, VIA EMAIL

SHOULD I REALLY STARVE A FEVER AND FEED A COLD?

Feeding a cold seems like common sense: we all need energy to fight an infection, so making sure we eat something is surely a good idea. And if it's in the form of soup, it also fits with the familiar advice from doctors about staying hydrated. In fact, there's some evidence that feeding a cold might have another, even more direct, benefit. In 2002, researchers at the Academic Medical Centre in Amsterdam reported that eating helps the immune system's ability to fight viruses, which cause colds. They found that levels of interferon gamma, a protein involved in the body's infection-fighting system, quadrupled after a meal. In contrast, avoiding food actually lowered interferon gamma levels. At least, that's what this study found, but it only involved six participants, and – perhaps surprisingly – has never been properly followed up. So given the lack of compelling evidence, you're probably best off being guided by your appetite when you have a cold – eat for energy, but don't force yourself to overeat.

And what about fasting to treat a fever? This one dates back to the Ancient Greeks, but there's no good evidence for it. Indeed, if it's true that eating does boost interferon gamma, then avoiding food could even be counterproductive. As with colds, the best things you can do for a fever are to keep yourself hydrated and get plenty of rest. *RM*

DEAR DOCTOR...

DELICATE ISSUES DEALT WITH BY *SCIENCE FOCUS* EXPERTS

WHY DO I ALWAYS CRY WHEN I WATCH FILMS ON A PLANE?

You're far from alone. Social media abounds with people sharing similar experiences. In 2017, Virgin Atlantic even went so far as to introduce special notifications on their in-flight entertainment systems to let passengers know when they were about to watch a tearjerker.

There has been little formal research into the reasons for what some have called the 'mile-cry club', but it's likely due to a combination of psychological and physiological factors. For starters, travel is often a fraught and emotional time – you might have just said farewell to loved ones before leaving, and then maybe you found it stressful battling the queues to make it through security on time. Of course, many people are also anxious about flying, and hurtling through the air at 35,000 feet can make us all feel a bit vulnerable. Add these elements together and many passengers are already in an emotionally delicate state before the weepy movie has even started.

On top of all this, there are the basic physical effects of altitude on the brain. The lower-than-normal air pressure in the cabin is known to induce mild hypoxia (reduced oxygen levels in the brain), which is associated with a raft of cognitive and emotional effects, including heightened negative moods and a diminished ability to handle stress. Put all this together, and it'd be pretty impressive if you didn't well up! ***CJ***

PHOEBE, SURREY

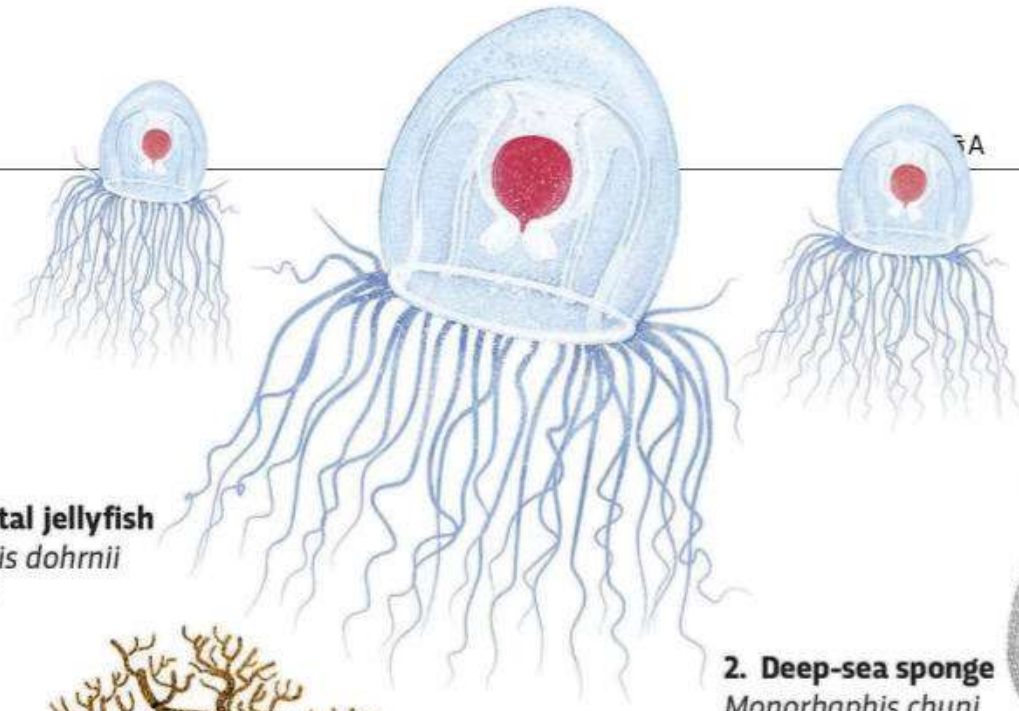
WHAT WERE THE 'OAKVILLE BLOBS'?

In August 1994, a resident of Oakville – a small city in Washington, US – reported translucent, gelatinous blobs, each about half the size of a rice grain, covering the ground. She said that they had rained down during the night, and believed that they may have caused her and her mother to subsequently develop flu-like symptoms. Over the next three weeks, there were another five reports in the local area of these strange blobs, with several people claiming that they had fallen ill as a result of contact with them. A microbiologist at the Washington State Department of Health found that the blobs contained two species of bacteria, although there was no suggestion that the bacteria were harmful.

Various theories have been suggested to explain this event, including, inevitably, classified military weapons testing, but there's no evidence to support this. Nor is there evidence for the idea that jellyfish were shredded into pieces and swept up into the stratosphere by US Air Force bombing practice in the nearby Pacific. It's possible that the blobs didn't fall from the sky at all, and simply appeared on the ground overnight. A similar substance called 'star jelly' has been mentioned in scientific reports and poetry since at least the 17th Century. Substances that people have called star jelly have come from a variety of sources: amphibians, algae, slime moulds, and even crystals of sodium polyacrylate, sometimes used in agriculture. In 2012, sodium polyacrylate absorbed water from a storm to form gelatinous blobs in Bournemouth. Maybe the Oakville blobs were something similar. ***LV***

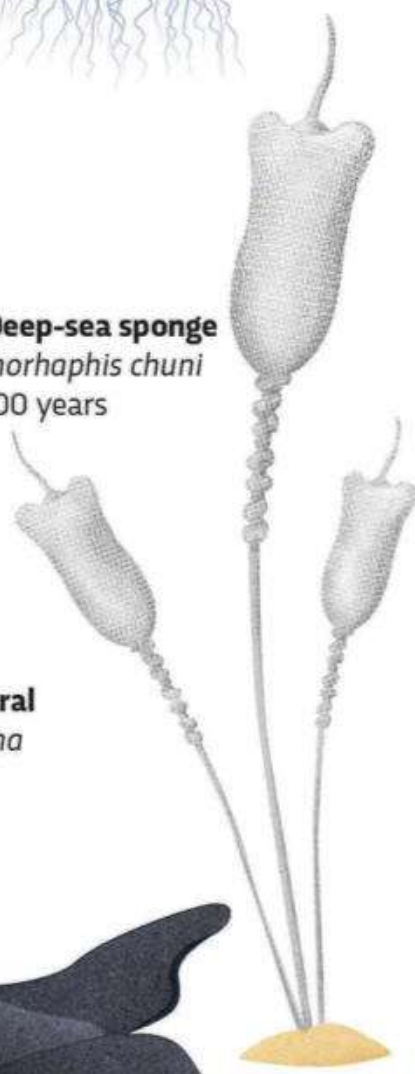
WILLIAM DEFALCO/YOUTUBE ILLUSTRATIONS: DANIEL BRIGHT

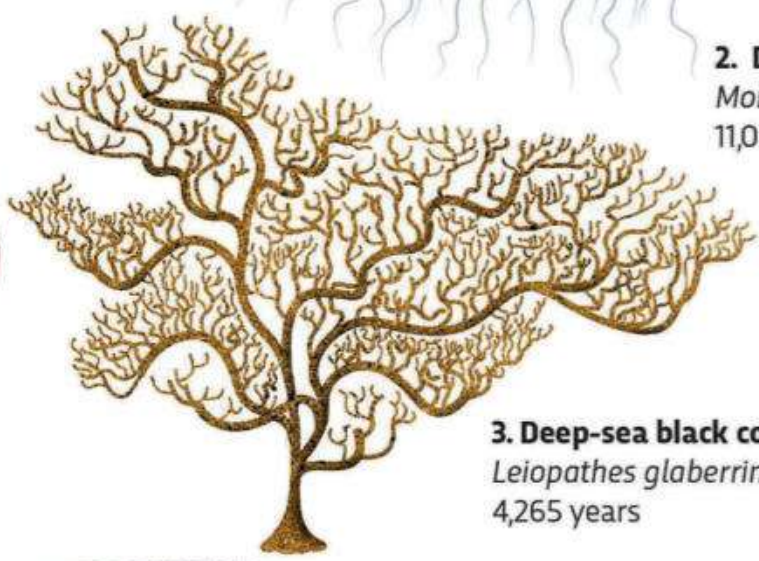
TOP 10...
LONGEST LIVING SEA CREATURES
(BY OLDEST KNOWN SPECIMEN)



1. Immortal jellyfish
Turritopsis dohrnii
Forever*

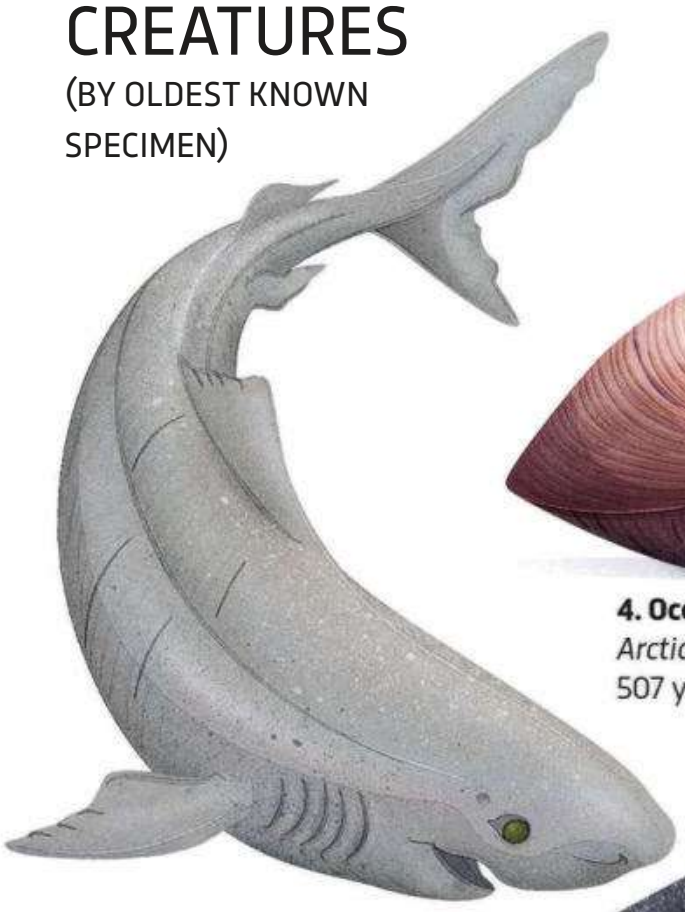
2. Deep-sea sponge
Monorhaphis chuni
11,000 years





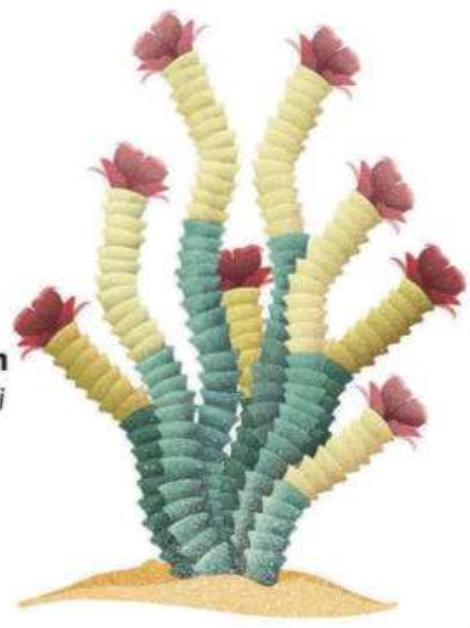
3. Deep-sea black coral
Leiopathes glaberrima
4,265 years

4. Ocean quahog
Arctica islandica
507 years

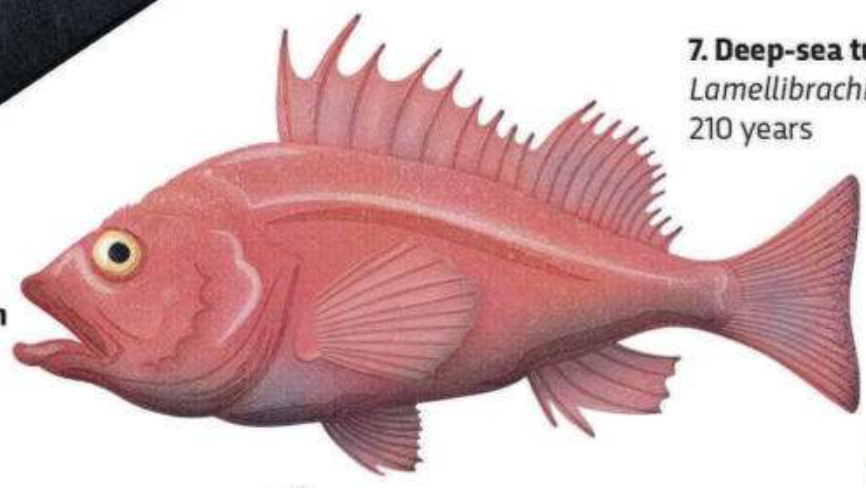


5. Greenland shark
Somniosus microcephalus
392 years

6. Bowhead whale
Balaena mysticetus
211 years

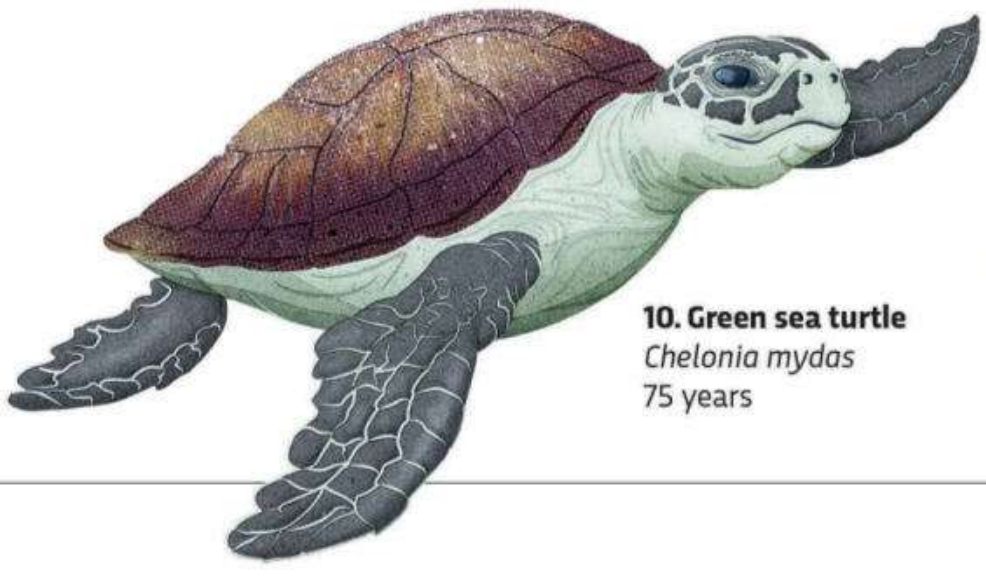


7. Deep-sea tube worm
Lamellibrachia luymesi
210 years



8. Rougheye rockfish
Sebastes aleutianus
205 years

9. American lobster
Homarus americanus
100 years

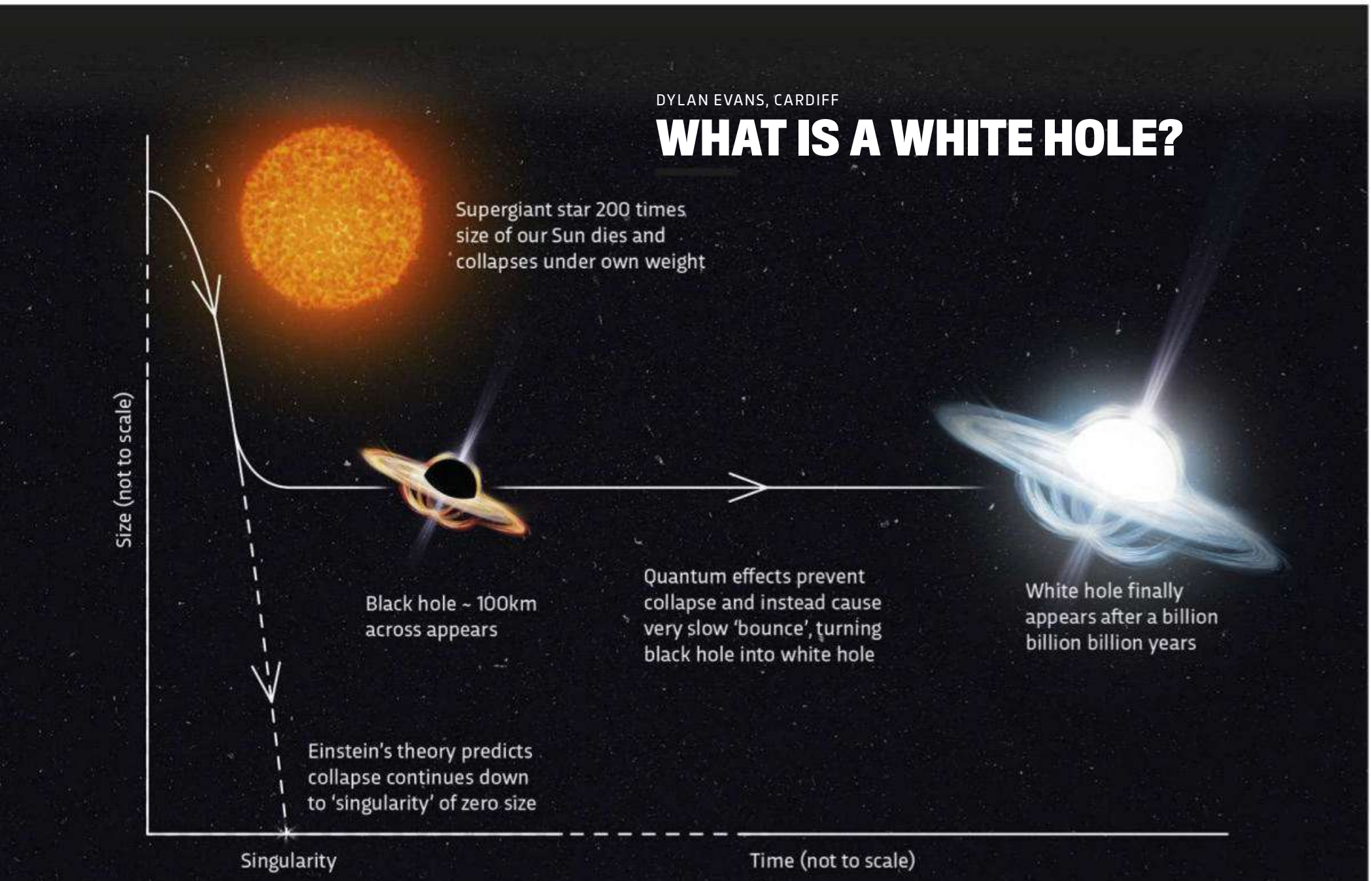


10. Green sea turtle
Chelonia mydas
75 years

*WHEN AN ADULT OF THIS JELLYFISH SPECIES DIES, IT HAS THE ABILITY TO RETURN TO ITS EARLIER 'POLYP' STATE TO BEGIN ITS LIFE AGAIN, ESSENTIALLY GIVING IT A BIOLOGICAL IMMORTALITY.

DYLAN EVANS, CARDIFF

WHAT IS A WHITE HOLE?


Supergiant star 200 times size of our Sun dies and collapses under own weight
Size (not to scale)
Black hole ~ 100km across appears
Quantum effects prevent collapse and instead cause very slow 'bounce', turning black hole into white hole
White hole finally appears after a billion billion billion years
Einstein's theory predicts collapse continues down to 'singularity' of zero size
Singularity
Time (not to scale)

A white hole is a bizarre cosmic object which is intensely bright, and from which matter gushes rather than disappears. In other words, it's the exact opposite of a black hole. But unlike black holes, there's no consensus about whether white holes exist, or how they'd be formed. They are predicted by Einstein's theory of gravity, and are most often mentioned in the context of 'wormholes', in which a black hole acts as the entry point to a tunnel through space and time, ending in a white hole somewhere else in the Universe. But this is deeply controversial, because Einstein's theory predicts the existence of a so-called singularity at the centre of black holes – a state of infinite gravity which would prevent anything from passing through to the white hole on the other side.

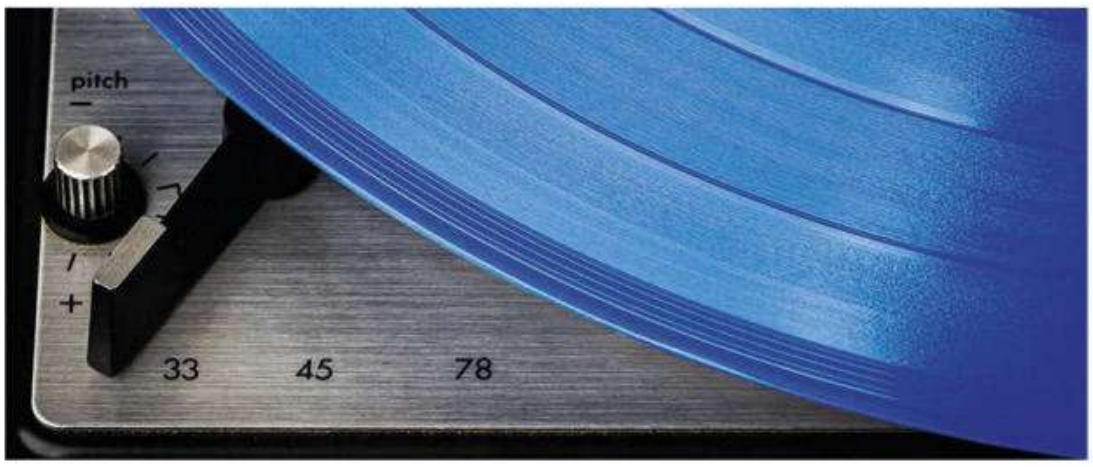
However, some theorists think that a combination of Einstein's theory and quantum theory points to a new way of thinking about white holes. Instead of being the 'exit' from a wormhole, they may be a slow-motion replay of the formation of the original black hole. The process starts when an old massive star collapses under its own weight and forms a black hole (see diagram, above). But then, quantum effects occurring around the surface of the black hole halt further collapse to a singularity, and instead begin to gradually turn the black hole into a white hole that's spewing out the original star matter again. The process is mind-bendingly slow, though, so we may be in for a very long wait to find out if white holes really exist. ***RM***

SAMANTHA THOMPSON, LUTON

WHEN I MAKE CHOCOLATE CHIP COOKIES, WHY DON'T THE CHOCOLATE CHIPS MELT IN THE OVEN?

Cooking chocolate tends to have less cocoa butter than eating chocolate, which raises the cooking chocolate's melting temperature and makes it more difficult to melt. However, the chocolate will still melt in the oven. The chocolate chips in your cookies are simply held in shape by the surrounding cookie mixture. When the cookies cool, the chips solidify again, so it looks as if they never melted. ***ED***

GETTY IMAGES X3, ALAMY ILLUSTRATION: DANIEL BRIGHT



AMMAR EL-BEIK, WOKINGHAM

WHY DOES A RECORDING INCREASE IN PITCH WHEN SPED UP?

Sounds are the result of air vibrating, and if they're reproduced at, say, twice the speed that they were originally recorded at, the vibrations hit our ear twice as many times per second – i.e. twice the original frequency, which makes them sound higher in pitch. In the case of musical notes, doubling the speed raises the pitch of each note by an octave. Some records exploit this effect, with trumpet players being recorded at half-speed so that when replayed at the right speed, they sound like they're hitting really high notes perfectly. ***RM***

CONNIE FOY, BUCKINGHAMSHIRE

HOW DOES BUBBLE WRAP BECOME BUBBLY?

Invented in the US in 1957, bubble wrap is made by heating a thin sheet of plastic film as it passes between perforated rollers. Air is blown through the holes in the rollers, to stretch half-dome bubbles in the sheet. Then a second layer of plastic is bonded underneath the sheet, to seal the air into individual bubbles. Bubble wrap can be recycled at some facilities, but there are more environmentally friendly options. One alternative, for example, uses kraft paper that's been stamped with a special pattern of slits, which allows it to be pulled into a honeycomb-like mesh that can be wrapped around fragile items. ***LV***

CROWDSCIENCE

Every week on BBC World Service, *CrowdScience* answers listeners' questions on life, Earth and the Universe. Tune in every Friday evening on BBC World Service, or catch up online at **bbcworldservice.com/crowdscience**

BBC WORLD SERVICE CROWD science

WHY DOES RUNNING WATER MAKE ME NEED THE TOILET?

Generations of parents will tell you about the running tap trick. Whether you're potty-training a toddler or trying to get a young kid to pee before bedtime, the trickling sound from a tap will help them. In hospital contexts too, urology nurses will use the sound of water to help patients who, as part of an examination, are in the awkward situation of needing to relieve themselves on demand in front of others. Recently, researchers even tested a smartphone app that played watery sounds to help urology patients pee.

Despite the familiarity of the trickle-sound technique, it remains far from fully understood. The most obvious theory for why it works is via a process of conditioning. The sound of a trickle of water, especially into a pool below, matches closely the sound of urinating into the bowl of a flush toilet. For many of us, the act of peeing has been associated with this sound multiple times a day, for years! The idea, then, is that hearing the trickle somehow triggers a conditioned reflex to pee.

However, this explanation can't account for the fact that people who've never used a flush toilet – as is the case with billions around the world – still reportedly experience the effect. An alternative theory is that the trickle sound makes us feel calm and safe, and so facilitates the activity of the 'parasympathetic nervous system'. This system acts to dampen down the 'sympathetic nervous system' that's responsible for the fight-or-flight response. The result is a physiological state that relaxes the muscles that control the bladder, making us feel the urge to go. ***CJ***

CHRIS MAYHEW

WHAT CAUSES WET DOG SMELL?

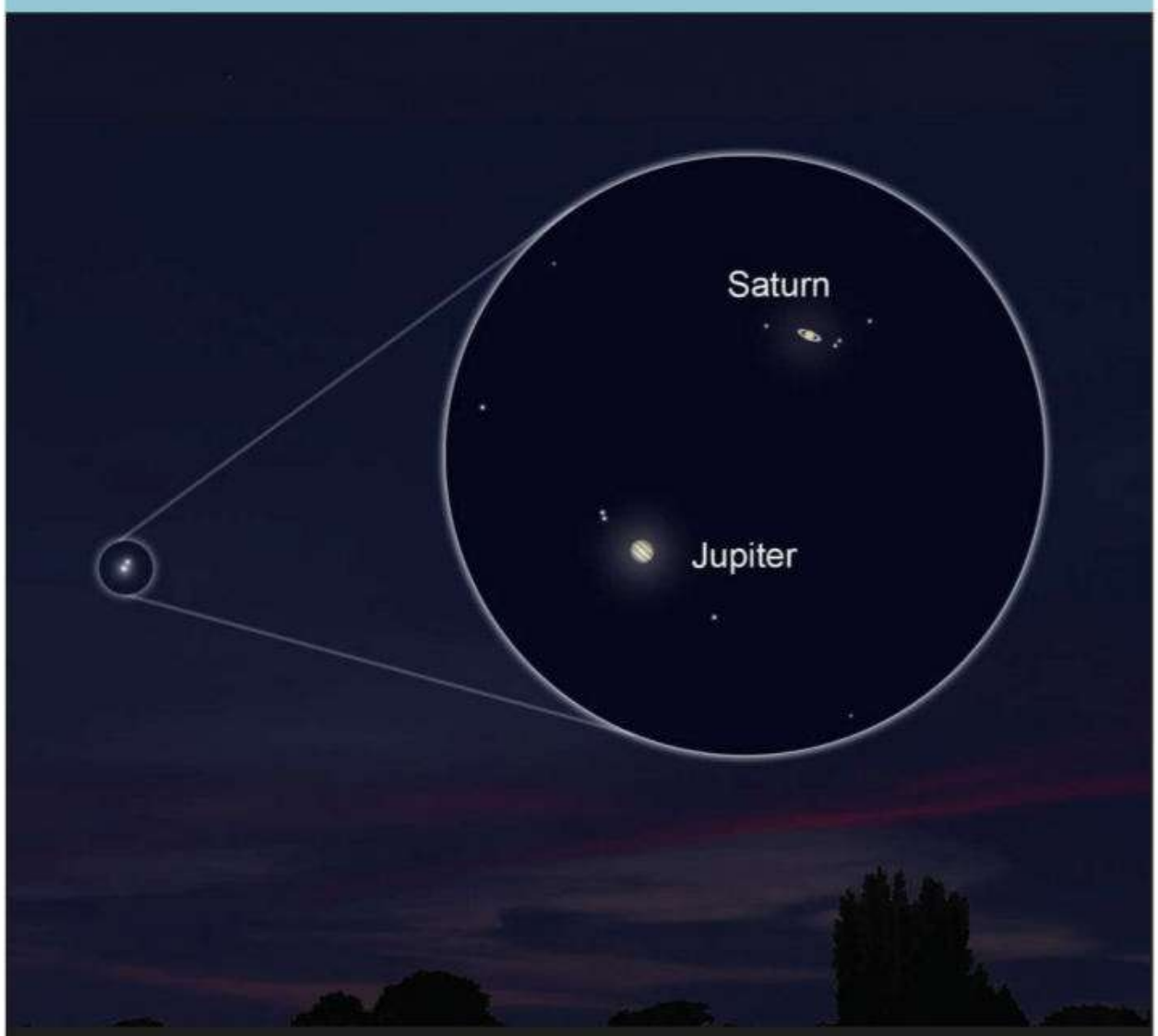
Mmm, the scent of wet dog: a heady aroma tinged with fruity and faecal notes. The distinctive odour comes not from the dog, but from the microorganisms (yeast and bacteria) that live in its fur. These emit pungent volatile compounds, which are released into the air as the water evaporates. This increases the humidity in the air surrounding the dog, and because humid air holds more odour molecules, the delicious smell becomes magnified further. And... breathe out. ***HP***

LILY JOHNSON

WHY DON'T SPIDERS BLEED TO DEATH IF THEY LOSE A LEG?

Check out 'Bob the Former Disabled Tarantula' on Facebook. This pet (now renamed Bobbi after she was discovered to be female) lost seven legs during an escape attempt, only to regrow them at her next moult, a few months later. She didn't bleed to death because when spiders lose legs, they usually come off at 'break points' – joints which contain muscles that constrict to minimise blood loss. If a leg becomes amputated *before* the break point, the spider still sheds its leg but only after additional blood loss. This can be fatal. ***HP***

ASTRONOMY FOR BEGINNERS



HOW CAN I SEE THE GREAT CONJUNCTION OF JUPITER AND SATURN?

WHEN: 21 DECEMBER

A 'great conjunction' is when Jupiter and Saturn come so close together in the sky that, to the naked eye, they appear as one bright planet. It happens around once every 20 years, and this year's great conjunction is even more special than usual, as the planets will appear closer together than they have since 1623. In reality, of course, Jupiter and Saturn aren't that close – it's a trick of perspective caused by their alignment as they orbit around the Sun.

To see the conjunction, look above the southwestern horizon on 21 December after sunset, at around 5pm. The planets will only be visible for about an hour before they set in the west, so remember to look as soon as darkness falls. If you miss the conjunction, don't worry: although the planets get closest on 21 December, you'll have a great view of the pair on any evening in December, looking southwest after sunset.

This month's astronomical event has some links to Christmas, too. In 1603, the astronomer Johannes Kepler calculated that, in the year 7 BC, there was a 'triple conjunction' between Jupiter and Saturn, in which the two planets met each other three times within around six months. He suggested that this rare event could have been the Star of Bethlehem, which, in the Bible, guided the wise men on their journey to Jesus. However, more recent calculations show the planets were likely too far apart in the sky to appear as one bright star.

Whether or not you believe the story of the journey and the star, the great conjunction of Jupiter and Saturn is one not to miss. If you have binoculars, you'll be able to see them as two separate planets, and if your binoculars are powerful enough, you might even be able to make out Saturn's rings. *AB*

GORDON TAYLOR, PLYMOUTH

WHAT IS 'RADIATION BREEDING'?

You might not have heard of it, but you've probably eaten a fruit or vegetable that's been created through radiation breeding. This technique exposes seeds to radiation in order to create mutations in the plant's DNA. Often, the mutated plants are useless. But occasionally, the genetic mutations give the plants useful new properties, like resistance to drought or disease, or higher yields.

Radiation breeding was first used in the 1920s, when X-rays were used to alter the properties of maize and barley. Today, it is carried out by firing beams of electrons, neutrons or charged particles (ions) at the seeds, or exposing them to radioactive sources like cobalt-60. The Mutant Variety Database, which collects information on plant varieties created through radiation breeding and other similar 'mutation breeding' techniques, logs over 3,000 improved varieties, including grapefruit, rice, wheat and barley. In Vietnam, around half the soya beans planted are mutant varieties.

Radiation breeding is different from genetic modification in that it only alters existing DNA – no new genetic material is introduced. The crops themselves are not radioactive, and given that billions of people have eaten them with no ill effects, it's unlikely they're harmful. Radiation breeding technology is also relatively cheap, so as the climate warms, the technique might provide a way for developing countries with limited resources to create drought-resistant crops. ***BHo***

QUESTION OF THE MONTH

ANGUS THORP, STAFFORDSHIRE

WHY IS IT MORE ANNOYING SEEING SOMEONE WEARING A FACE MASK INCORRECTLY THAN SEEING SOMEONE NOT WEARING A MASK AT ALL?

If you wear a mask incorrectly, such as below your nose or with baggy sides, you might as well not be wearing one at all. When we see someone doing this, not only does it mean that the person isn't protecting those around them, but it naturally makes us worry that they *think* they are protecting people when they're not, thus raising the risk of them being complacent about other precautions like social distancing.

What's more, if we suspect that the person is *knowingly* wearing their mask incorrectly, this is likely to arouse our deep-seated dislike of cheats – people who try to surreptitiously put their own interests (in this case, their comfort) above those of the wider community. ***CJ***

WINNER

Angus wins a **Papalook HD video webcam**, worth £85.99. Even in low light conditions it offers good clarity, while its omnidirectional mic filters out background noise for purer sound. It's easy to set up via USB and is compatible with Mac, Windows, Chrome and Android. **papalook.com**

EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM**

GETTY IMAGES X2, ALAMY, SHUTTERSTOCK ILLUSTRATION: PETE LAWRENCE

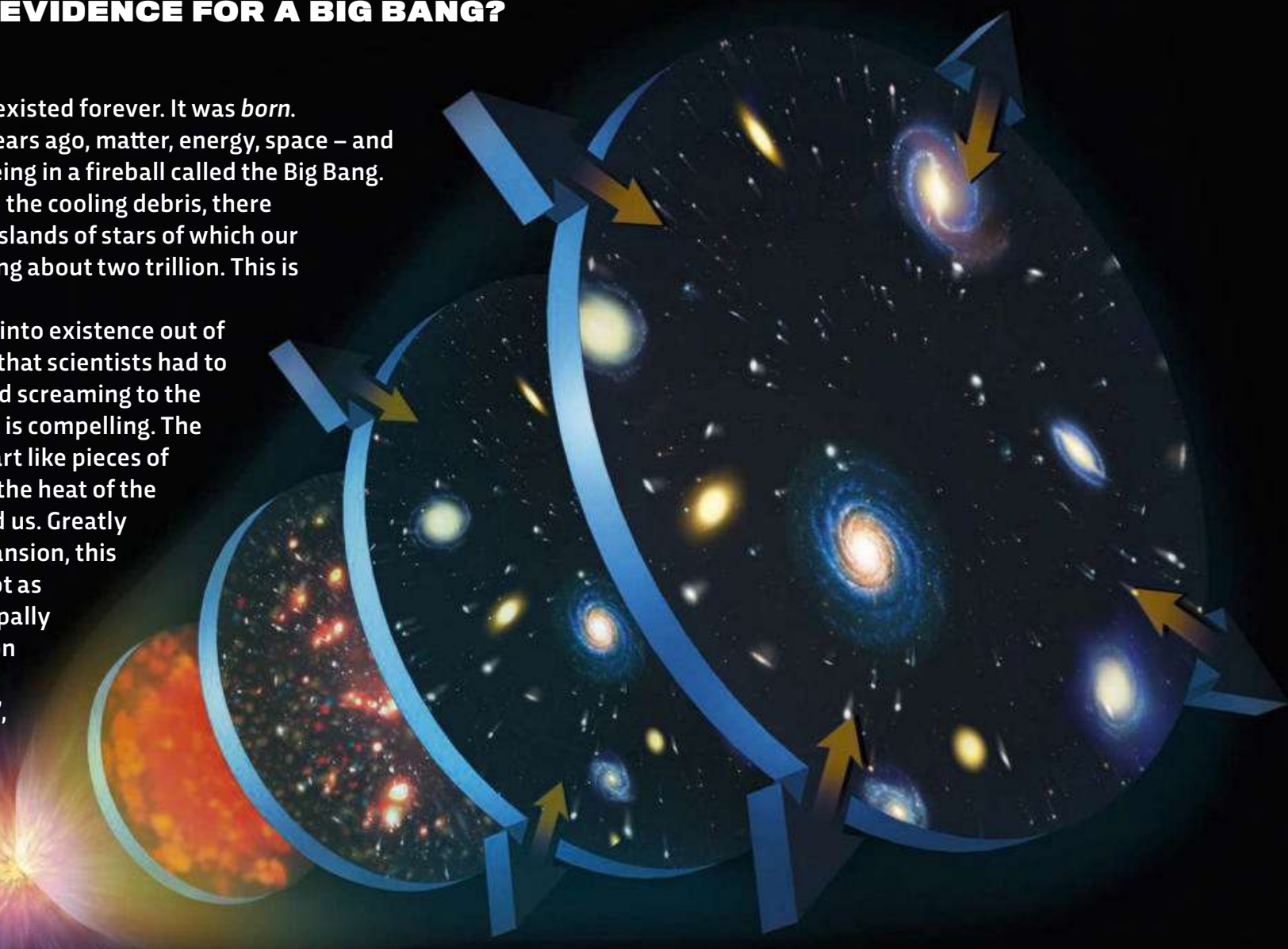
THE EXPLAINER

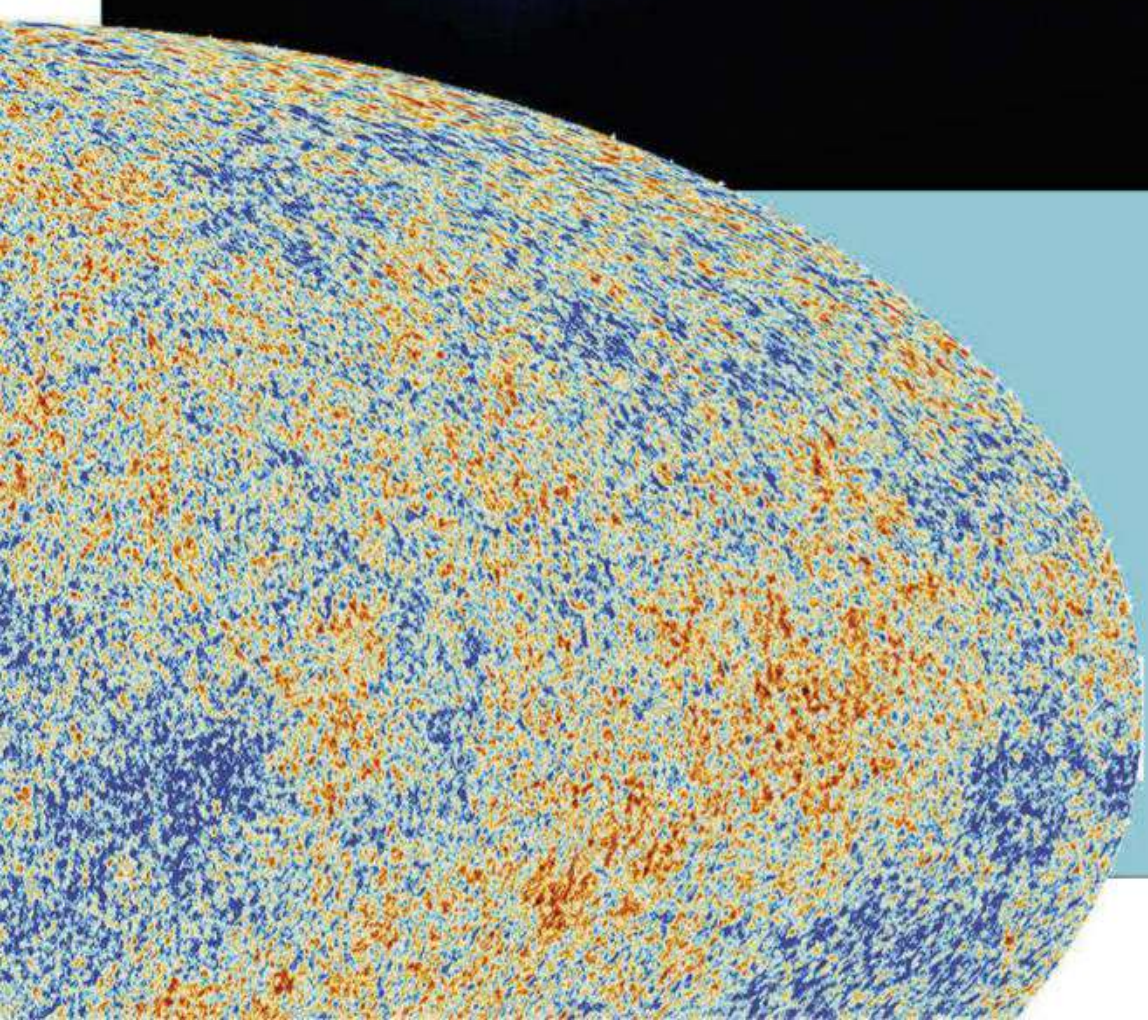
WHAT WAS THE BIG BANG?

WHAT IS THE EVIDENCE FOR A BIG BANG?

The Universe has not existed forever. It was *born*. Around 13.82 billion years ago, matter, energy, space – and time – erupted into being in a fireball called the Big Bang. It expanded and, from the cooling debris, there congealed galaxies – islands of stars of which our Milky Way is one among about two trillion. This is the Big Bang theory.

A universe popping into existence out of nothing is so bonkers that scientists had to be dragged kicking and screaming to the idea. But the evidence is compelling. The galaxies are flying apart like pieces of cosmic shrapnel. And the heat of the Big Bang is still around us. Greatly cooled by cosmic expansion, this 'afterglow' appears not as visible light but principally as microwave radiation – the 'cosmic background radiation', which was discovered by radio astronomers in 1965.



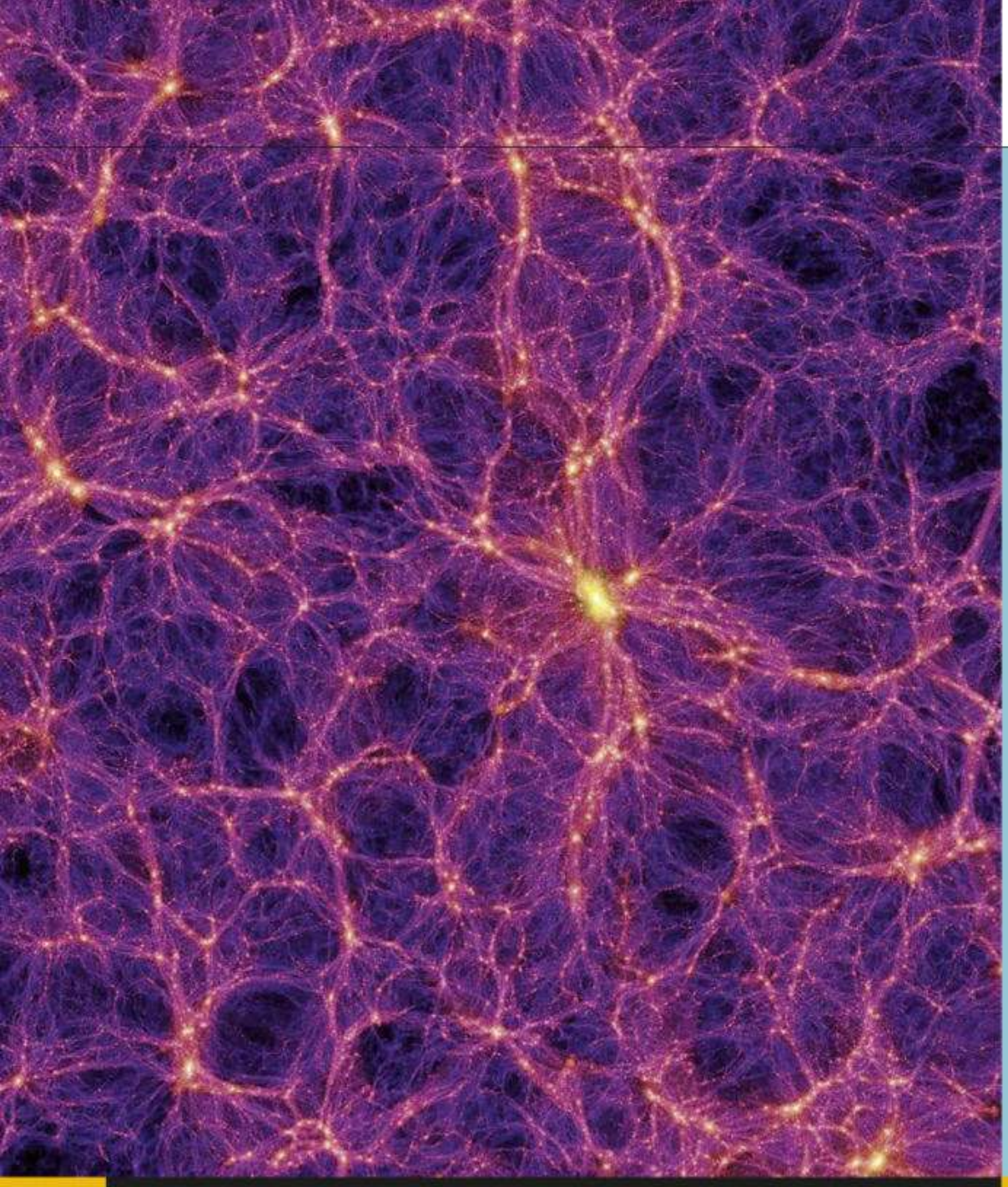


WHERE DID THE BIG BANG HAPPEN?

When a stick of dynamite explodes, the detonation occurs in one place and shrapnel flies into the void. In the Big Bang, there was no centre and no pre-existing void, so it didn't happen at any 'location'. Space itself popped into existence and began expanding everywhere at once.

Astronomy books often liken the Universe to a rising cake, with raisins representing galaxies. As the cake grows, raisins recede from each other, with no centre of expansion – just like the Big Bang. But of course, a cake has an edge, unlike the Universe, which may go on forever. No analogy is perfect!

SCIENCE PHOTO LIBRARY X4, ESA



WHAT ARE THE PROBLEMS WITH THE BIG BANG THEORY?

The basic idea – that the Universe began hot and dense and has been expanding and cooling ever since – is incontrovertible. But cosmologists have had to make tweaks to the theory, to account for certain observations.

First, in the standard Big Bang model, galaxies grow by gravitationally pulling in matter. But if this were the only thing going on, it would take much longer than 13.82 billion years for them to form. Astronomers fix this by postulating that the visible stars and galaxies are outweighed by a factor of six by invisible 'dark matter', the extra gravity of which speeds up galaxy formation.

Second, the basic Big Bang predicts that the gravitational attraction between the galaxies acts like a web of elastic, slowing cosmic expansion. However, in 1998, astronomers discovered that the Universe's expansion is speeding up. They fix this by postulating the existence of 'dark energy', which is invisible, fills space and has repulsive gravity.

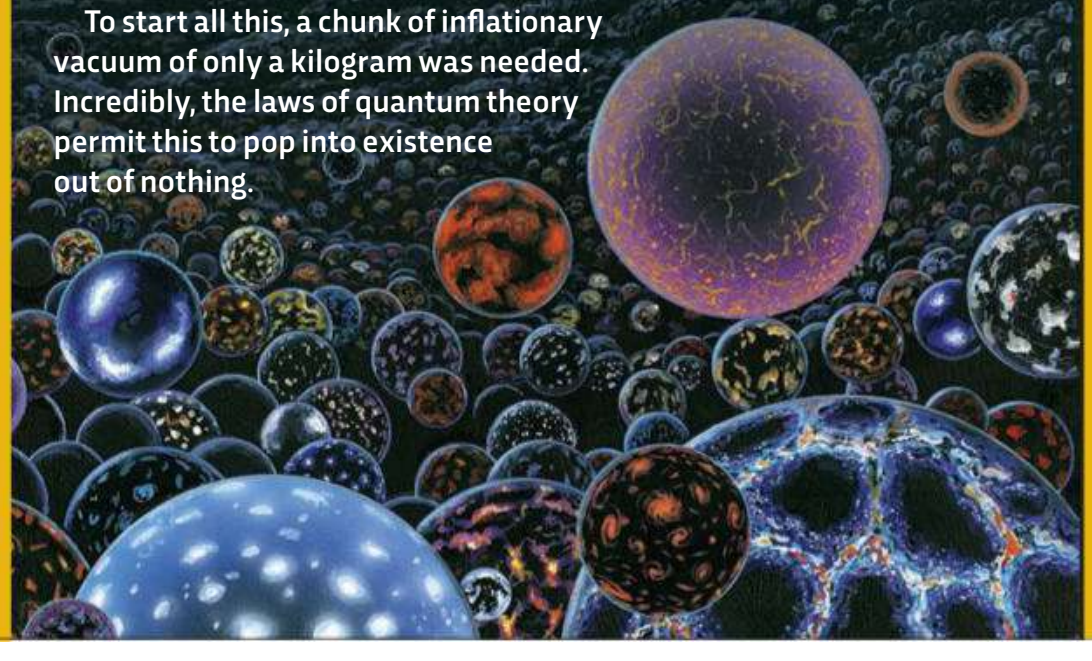
A final tweak to the basic theory is needed to explain why the Universe has the same temperature everywhere. To account for this, astronomers think that the Universe early on was smaller than expected, then underwent a super-fast expansion in its first split-second – an 'inflation'. This was driven by an 'inflationary vacuum', a high-energy version of the vacuum that exists in space today.

WAS THE BIG BANG A ONE-OFF?

In the beginning of the Big Bang there was the inflationary vacuum. When it doubled its volume, it doubled its energy; when it tripled its volume, it tripled its energy. If banknotes were like this and you pulled apart a stack, ever more would appear. Physicists call inflation the 'ultimate free lunch'!

The inflationary vacuum expanded ever faster. But it was a 'quantum' thing. And quantum things are fundamentally unpredictable. Randomly, all over the inflationary vacuum, parts of it 'decayed' into ordinary, everyday vacuum. Think of tiny bubbles forming in a vast ocean. In each bubble, the inflationary vacuum disappeared, but its enormous energy had to go somewhere. It went into creating matter and heating it. It went into creating a Big Bang. Our Big Bang Universe is merely one such bubble among a possible infinity of other Big Bang universes in the ever-expanding inflationary vacuum!

To start all this, a chunk of inflationary vacuum of only a kilogram was needed. Incredibly, the laws of quantum theory permit this to pop into existence out of nothing.



WHAT HAPPENED BEFORE THE BIG BANG?

The twin pillars of modern physics are Einstein's General Relativity and quantum theory. The former reigns supreme in the large-scale Universe, while the latter orchestrates the small-scale world of atoms and their constituents. They have resisted a merger, which is a problem because, in the Big Bang, the Universe was small. To understand how it emerged, it is essential to unite Einstein's theory with quantum theory. The best candidate is 'string theory', which views the basic building blocks of reality as tiny strings of mass-energy vibrating in 10-dimensional space-time. Only if we obtain such a theory will we be able to answer the ultimate questions: What is space? What is time? What is the Universe? And where did it come from?

by MARCUS CHOWN

Marcus is a writer, broadcaster and former radio astronomer. His latest book is The Magicians *(£14.99, Faber & Faber).*

THE BBC SCIENCE FOCUS DRAW AN ALIEN COMPETITION JUDGED BY DARA Ó BRIAIN

We want YOU to draw what you think an extraterrestrial being might look like. But where do you begin? Zoologist and astrobiologist ***Dr Arik Kershenbaum*** *reveals the clues right here on Earth that will help you design your alien…*

Lessons from life on Earth

Although the Universe is full of unexpected surprises – planets with seas of petrol, worlds with diamonds raining from the sky – life isn't completely unbounded. Life follows rules. If you know what those rules are, you're going to know something about what aliens are like.

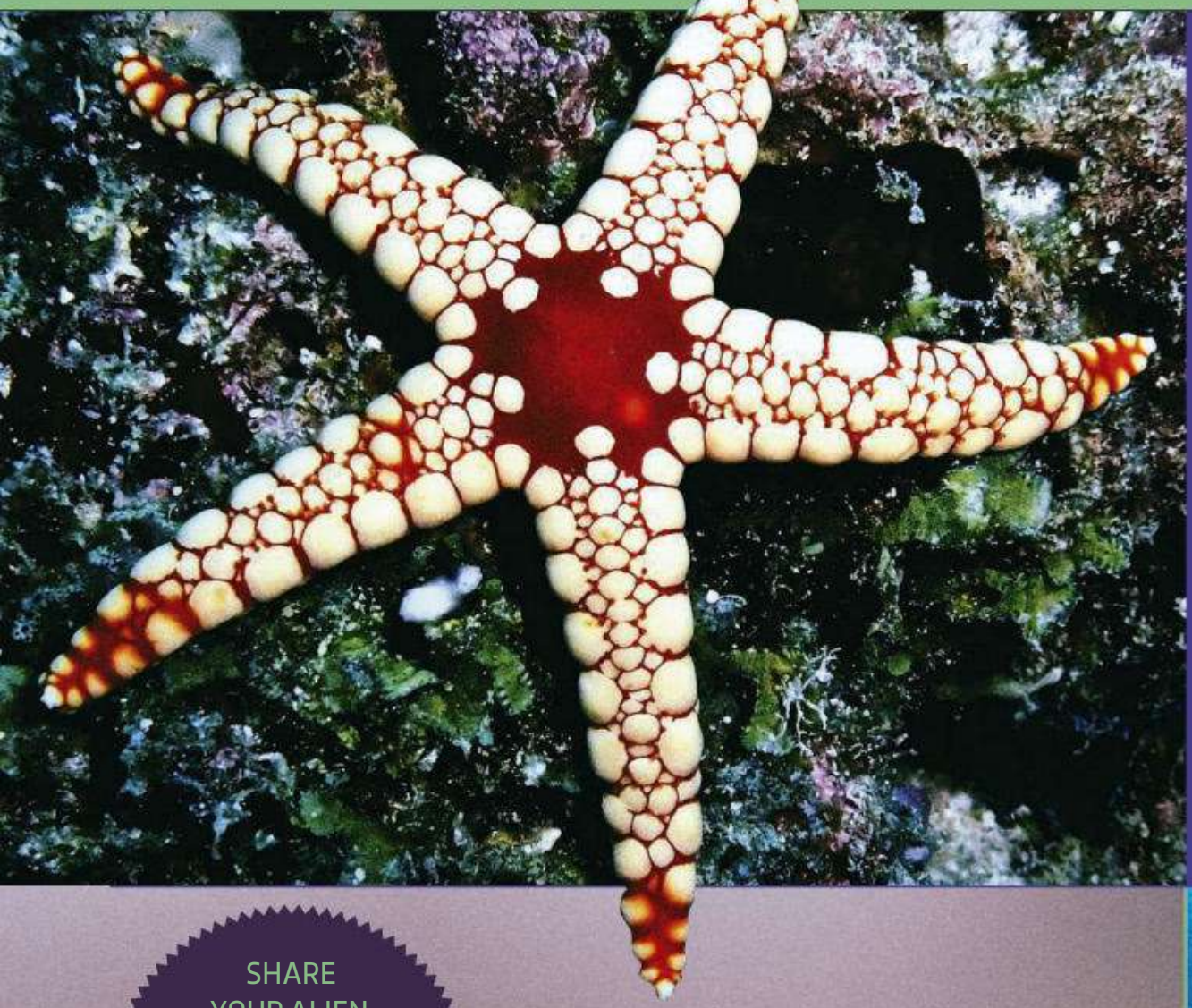
The most important rule is that life arises by natural selection. Life adapts to its environment. Complex aliens will have evolved from simple aliens, to solve the problems on their planet. Problems like finding food, avoiding becoming someone else's food, and reproducing.

Earthly problems are also problems that need to be solved on alien worlds. And when we look at how Earth animals solve them, we can see how aliens might do it too.

GETTY IMAGES X4

WHAT WILL THEIR LIVES BE LIKE?

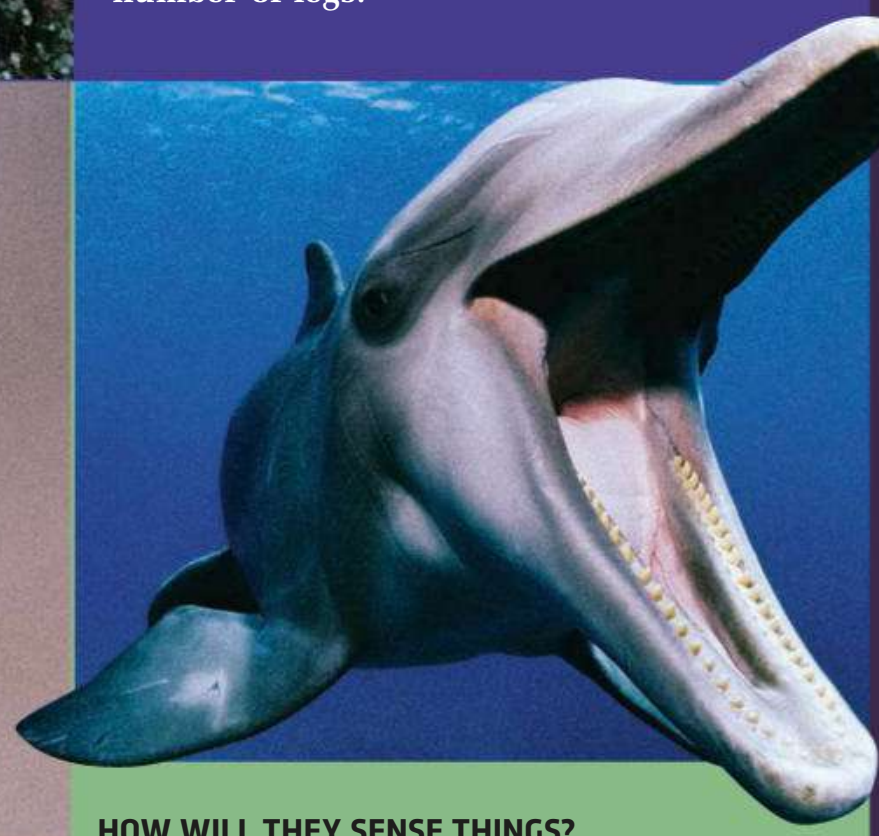
The trick is to think about how aliens live. What do they really need? The first thing they need is food. All life needs energy, and energy comes mostly from two places, from sunlight (or maybe other kinds of heat), and from other creatures. Plants eat sunlight, but animals eat other animals and plants. Alien worlds will have predators, and they will have prey. Predators will need to be like those on Earth: fast or stealthy. Prey will need to defend themselves using camouflage or armour. And maybe, like on Earth, some creatures will solve their problems in a special way: by grouping together. Wolves hunt in a pack, and zebras stay in a herd to keep safe from lions. Some aliens will be solitary, but some will also be social.



SHARE YOUR ALIEN DRAWINGS VIA THE HASHTAG **#MYALIENFORSF** BY 5 JANUARY 2021

WILL THEY BE SYMMETRICAL?

Life on Earth began on the sea floor, and so our ancestors crawled. Aliens that evolved on a floor will crawl too. But if you crawl, you probably have a front and a back – and that means you have a left and a right side too. Symmetrical animals move so much faster than non-symmetrical ones: they have a real advantage. That doesn't mean that circular (or even triangular) aliens are impossible, but think about how they evolved: why did they get an advantage by being circular or triangular? Maybe circular creatures could evolve in a bottomless ocean, where there's no advantage to crawling. If you do have simple left-right symmetry like us, you'll likely have an even number of legs too: the same number on the left and on the right. But if that symmetry doesn't exist, you could have almost any number of legs!



HOW WILL THEY MOVE?

Of course, if someone is going to eat you, you'd better move. And they'd better move to catch you. So what are the different methods of locomotion? You can move through a liquid or gas, like fish and birds. Or you can move on a solid surface. Maybe you can move through solid earth – but that's not easy. If you're moving on a solid surface, there's so much friction, so it helps if you can lift yourself up a little bit. That's either with legs, or with slime, like a slug. Legs are incredibly useful, and are bound to be found on lots of other planets. If you move through a gas or liquid, you have a few more options. Wings or fins are an excellent choice, and jet propulsion (like a squid) might also work as well.

HOW WILL THEY SENSE THINGS?

If you're looking for food (and all life is), you need to sense the world. Even plants grow towards sunlight. The ways that life senses its environment on Earth pretty much sums up almost all the ways that it can be done. There's sight and hearing, of course, but also smell (sensing the presence of chemicals), and quite a few species can sense electrical fields. Some animals even use magnetic fields to find their way around. Light and sound are particularly good ways to sense the world: they're fast, detailed, and easy to detect. But they both have disadvantages. In an underground ocean, there may not be any light at all. And sound doesn't travel well in a thin atmosphere like on Mars. It's the physical constraints of a planet that determine which sense will work best, but one or both of sight and hearing are likely to be important.

CONCLUSION

The rules of nature are real rules. We can use the rules of biology to predict alien life, just like we can use the rules of physics to predict the amount of gravity. Science fiction has distorted our impression of what aliens must be like, appealing to our fears, or our hopes, or designing them for entertainment value. But we are explorers in the Universe. We don't want to be completely surprised by what we find, and we are lucky enough to be equipped with a good understanding of how life exists, and how it becomes more diverse and complex. And if we do find that aliens have lots in common with life on Earth, then that makes our world a special place, even if not unique.

by DR ARIK KERSHENBAUM

*Arik is a zoologist at the University of Cambridge and is on the board of advisors for **METI.org**, a think tank on the topic of messaging extraterrestrial intelligence. He is the author of* The Zoologist's Guide To The Galaxy *(£18.99, Viking), which is out now.*

ENVIRONMENTS ON OTHER WORLDS

MARS

Despite its apparent similarity to deserts on Earth, Mars is different from any environment on this planet. Yes, it's dry, but that is because the planet's atmosphere has been largely stripped away, along with its water vapour. Mars also has much less gravity than Earth – you'd weigh about one-third of what you do here. Even in the driest desert on Earth, rocks are still heavier than on Mars!

EUROPA AND ENCELADUS

These two small moons of Jupiter and Saturn are thought to have vast underground oceans under their thick ice surfaces. Dark, cold and salty, with very high pressures, could the deep sea trenches of oceans on Earth give us a clue of the environments on these moons? Astrobiologists see these moons as one of the top priorities in the search for alien life.

VENUS

Although the surface of Venus is hot (450°C), high up in the atmosphere the temperature and pressure is similar to that of the Earth. Only one problem: the clouds are made of concentrated sulphuric acid. Weird bacteria are known to exist in highly acidic water on Earth, such as in Ethiopia's Dallol pools. But the acid clouds on Venus are more than 1,000 billion times more acidic than Dallol!

TRAPPIST-1E

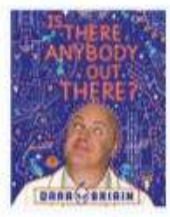
Orbiting a star 40 light-years away, this may be the planet most similar to Earth that we have discovered so far. There may even be liquid water on the surface. But we won't know more about it until new space telescopes are launched next year to look for signs of life outside the Solar System.

NASA/JPL X4, BBC

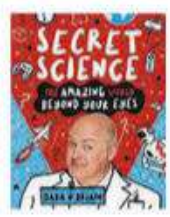
HOW TO ENTER

Have a read of these pages for inspiration, then draw a picture of an alien and share it with us on Twitter or Instagram using the hashtag #MyAlienForSF Alternatively, you can send in a photo of your alien to **reply@sciencefocus.com** with MyAlienForSF in the subject line of the email. Comedian, science presenter and author Dara Ó Briain will pick his favourite from the entries, with the winner receiving a bundle of his science books. Entries must be received by 5 January 2021.*

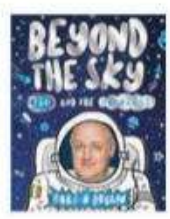
PRIZE



IS THERE ANYBODY OUT THERE?
RRP £12.99



SECRET SCIENCE: THE AMAZING WORLD BEYOND YOUR EYES
RRP £7.99



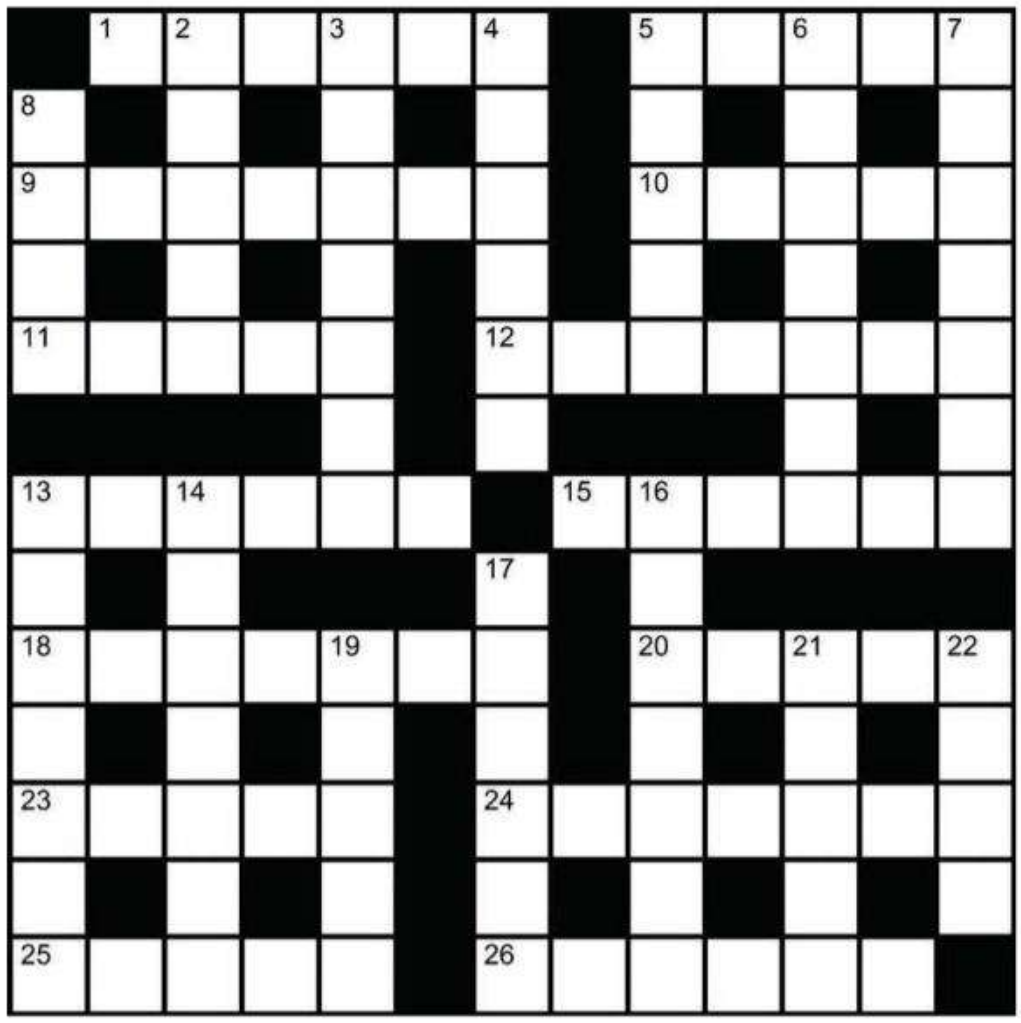
BEYOND THE SKY: YOU AND THE UNIVERSE
RRP £7.99

Terms and conditions

** The Promoter is Immediate Media Company Bristol Limited. This promotion is in no way sponsored, endorsed, administered by, or associated with Twitter/Instagram. The BBC Code of Conduct for competitions can be found at **www.bbc.co.uk/competitioncode/** and all BBC magazines comply with the Code. The promotion is open to all residents of the UK, including the Channel Islands, aged eight years or older, except the Promoter's employees or contractors and anyone connected with the promotion or their direct family members. Children under 18 must have parent/guardian permission.*
*The closing date for entries is 5pm on 5 January 2021. Entrants should enter by email, or via Twitter or Instagram. Entries received after the closing date of the promotion will not be considered. The winner will be notified within 28 days of the close of the promotion by email or via social media. If the winner cannot be contacted, or fails to respond within 28 days of such notification being sent, the Promoter reserves the right to offer the prize to a runner-up, or to re-offer the prize in any future promotion. For full terms and conditions, visit **sciencefocus.com/science/draw-an-alien-competition***

CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

1 They wrap fish for weighing device (6)
5 Round pedal (5)
9 Nowadays, some poetry is hostile (7)
10 Composer's ecstasy (5)
11 Plate shaped like an object in nature (5)
12 Material fools family (7)
13 Working blind around university city (6)
15 Cadge from a cleaner (6)
18 Frenchman ordered the cab to see Scottish play (7)
20 Forbidden to throw a boot (5)
23 Gourmets initially turn out to sound like a pig (5)
24 Woman registered as outstanding (7)
25 Flying geese hide energy inside (5)
26 Terrible to rent out (6)

DOWN

2 Desire to get firm with doctor (5)
3 Role played by garland and siren (7)
4 Audible wave from Arab leader (6)
5 Youngster and journalist, not just squared (5)
6 Yellow bird (7)
7 The nature of perfume (7)
8 Complain of vehicle parking (4)
13 Compensation for block takes a long time (7)
14 Wager unfinished conviction has followed since (7)
16 Doctor's charge is obvious around island (7)
17 Reach out, grabbing small, second drink (6)
19 Consumed by school, say (5)
21 European follows awfully glib nonsense (5)
22 Average artist has something to eat (4)

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

NEXT ISSUE

REWILDING

Can it save our wildlife and help temper climate change?

GETTY IMAGES

PLUS

SWARM INTELLIGENCE

Vast swarms of small, cheap, simple satellites could change the way we see and protect our planet.

CRACKS IN COSMOLOGY

In terms of our understanding of the Universe, some things don't add up.

ON SALE 29 DEC

SF

A SCIENTIST'S GUIDE TO LIFE

HOW TO SURVIVE CHRISTMAS

IT'S THE MOST WONDERFUL TIME OF THE YEAR... BUT LET'S BE HONEST, IT CAN ALSO BE QUITE STRESSFUL. THIS MONTH, CLINICAL PSYCHOLOGIST **LINDA BLAIR** GIVES US HER TOP TIPS ON HOW TO SURVIVE CHRISTMAS

DON'T START PLAYING THE CHRISTMAS MUSIC TOO EARLY.

Research suggests that when you hear a song for the first time, it's more challenging than enjoyable because your brain has to figure it out. After a time, you come to love it because you know it, but then if you hear it too often, the song becomes irritating. That's what happens with Christmas music. It can become really draining.

COMMUNICATION IS KEY.

I once had a call from a patient who was panicked when a relative showed up for Christmas with a new, unannounced partner. Tell your hosts, 'I will arrive at this time on this day, and I will be bringing my vegan girlfriend, Claire, with me.' Similarly, if you're the host, say, 'we'll do presents at 11am, lunch at 1pm and I'll order taxis for 4pm.' This will help to minimise stress and create a useful agenda. It'll also help to deploy guests who are likely to overstay their welcome!

MAKE SOME SPACE.

Experiments show that when mammals are crowded, they become aggressive. We're no different, so perhaps your relatives can stay in a local B&B. If they stay with you, make sure everyone has some private space, however modest.

Suggest that everyone takes a little daily exercise, preferably outdoors. It's a good way to boost levels of feel-good endorphins.

DON'T BE A MARTYR.

People will feel guilty if the host takes on all the jobs, and then makes clear that they are exhausted. As people arrive, have them pick a job out of a hat. Someone sets the table. Someone else washes up… then everyone knows what is expected of them.

CHRISTMAS DOESN'T COME AT A GOOD TIME.

Why do we have Christmas when we do?! There's little daylight to trigger endorphins and we're worn out from parties, finishing projects for work, and getting things ready. When you're tired, you tend to act emotionally rather than logically, which can lead to confrontations. Make sure you prioritise a good night's sleep.

ACCEPT THE WAY THAT PEOPLE ARE.

Dealing with a racist relative? Brushing off criticisms about lumpy gravy? Don't expect people to change their opinions or behave in ways you want them to. What they say is what they say. It's your choice whether to get annoyed. There's also immense power in silence. Let them talk while you listen. Eventually they'll trip themselves up, and if you start getting annoyed, breathe in slowly through the nose and then out through the mouth 10 times.

PERFECTION IS OVERRATED.

When you ask people to think of their best Christmas, they often remember the ones that went wrong… when the oven broke so they had to have peanut butter sandwiches, or when snow blocked the roads and everyone went sledging. We don't remember perfection. We do remember exceptions, so don't put too much pressure on yourself. Just enjoy whatever happens – and remember, laughter is contagious! SF

LINDA BLAIR

Linda is an associate fellow of the British Psychological Society. Her soothing book, The Key To Calm *(£16.99, Yellow Kite), is available now.* ***Interviewed by Dr Helen Pilcher.***

NEED TO KNOW...

1

Don't start listening to your favourite Christmas albums too early.

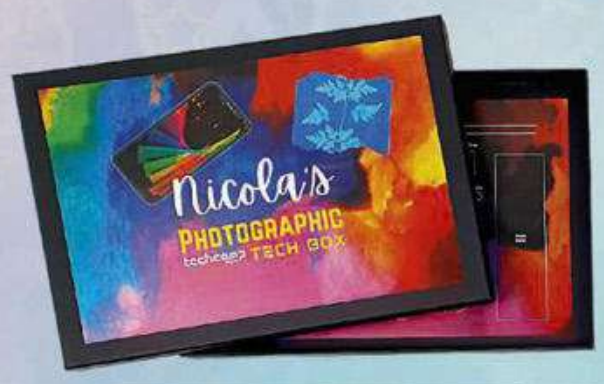
2

To be a great host and guest, ensure you communicate requirements before the big day.

3

Try to chill out and don't attempt perfection – just enjoy the day!

ILLUSTRATION: NOAH BAVONESE



Looking for the **Ultimate Creative GIFT?**

Personalised from just **TECH BOXES £39**

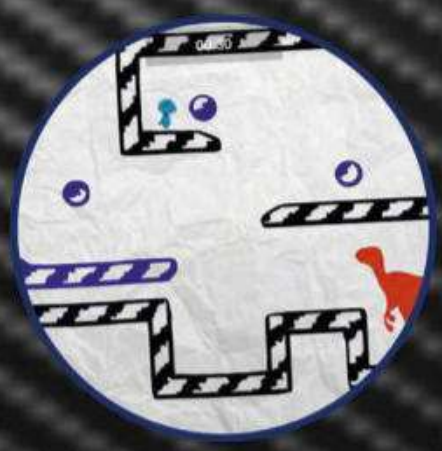
by techcamp.org.uk

PHOTOGRAPHIC TECH BOX

Build a smartphone camera stand & LED torches, create stunning light paintings and 'blueprint' sun photos and T-Shirts

SMARTPHONE LAMP TECH BOX

Build and program your own colour-changing lamp complete with smartphone control, automatic sleep function, and other custom features



GAMES & ANIMATION TECH BOX

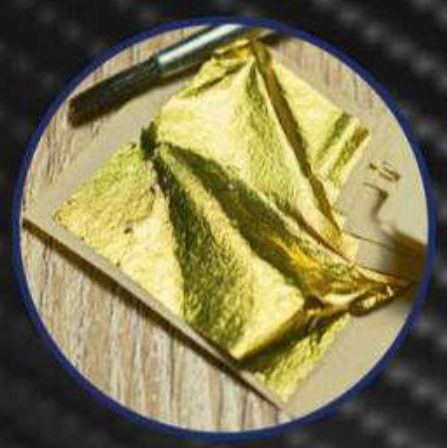
Create a smartphone document camera and design your own animations and playable games in minutes using a whiteboard

TECH PAINTING TECH BOX

Create the most unusual gift cards and paintings as you experiment with the latest in smart paints that respond to heat, light & moisture

SMART MATERIALS TECH BOX

Experiment with a dozen of the latest materials including super-absorbent polymers, metals that remember their shape, and nano materials modelled on the feet of Geckos!



GOLD, MYRRH & FRANKINCENSE

Yes, this box ships with real gold! The ancient meets the modern as you learn gilding, create soaps, make candles and discover the magic of Gold, Myrrh and Frankincense

Why should kids have all the fun ?

- Our Tech Boxes are simple enough for ages 8+ and sophisticated enough for adults
- Online video lessons and free support
- Personalise any box with a name for free

Reserve your kits for Xmas 2020 now at www.techcamp.org.uk/techbox

Scan for more info

Switch to the AA for a different kind of breakdown service

- ✔ Unlimited call-outs mean we're there when you need us
- ✔ Tap & track app lets you follow our Patrol to your side
- ✔ We'll usually fix you within 30 minutes of arrival
- ✔ Upgrade to Smart Breakdown to track engine faults in real time
- ✔ Join many other Members in saving over £55 a year with discounts at Greene King, Farmhouse Inns, IMO and lots more.

Buy breakdown cover from

£39

a year

and get a

£20

Boots or M&S EST. 1884

gift card

Buy online at

theaa.com/card8

or call 0800 072 9419

and quote ref. A5740

AA

Breakdown cover from £39: price is for Annual UK Roadside Vehicle Membership. Other levels of cover are also available. Offer is not available for existing Members or at renewal. Cover must be paid by continuous payment method. We'll use your payment details to renew your cover after 12 months. You'll receive a renewal invitation beforehand so you'll have plenty of time to change or cancel your cover. Offer not available in conjunction with any other offer online or in a breakdown situation. If you're buying online please use the website link specified, otherwise you will not receive the offer. **Gift card:** please allow 6 weeks from your policy start date for delivery and processing provided you haven't cancelled your policy. Card is redeemable online so you must have a valid e-mail address. Offer closing date: 28/02/21. **Unlimited call outs:** repeat call outs for the same fault within 28 days will not be covered. 30 minutes attendance: based on an average of all AA attended breakdowns 1 August 2018 – 31 July 2019. **Smart Breakdown and Tap and Track App:** subject to network coverage. **Member Benefits** saving value calculated based on the top 10% of Members by Member benefit redemptions between 01/03/2019 and 29/02/2020. For further information visit: theaa.com/member-benefits. All information correct at time of print November 2020.